ORIGINAL

Study on the impact of the ITER activities in the EU

Final report

Trinomics

Contract details

European Commission – DG Energy D.4.
Study on the impact of the ITER project activities in the EU (Ref. Ares (2017) 1939420
ENER/D4/2017-458

Presented by

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Date

Rotterdam, 4 April 2018

Disclaimer

Rotterdam, 4th April 2018

Client: European Commission - DG Energy D.4

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Abstract

English

This report presents an analysis of the impacts of the spending on ITER by F4E. It provides a detailed analysis of the in-kind contributions funded by F4E, and an analysis of future payments. Using the E3ME econometric model an estimate of the impacts on GVA and employment was made, this shows that spending on ITER is delivering significant benefits already, almost equivalent to the spending by F4E. Potential impacts of spin-offs further increase the economic impact. A survey of contracted firms and a series of case studies confirms these impacts and demonstrates the multiple other economic benefits to firms.

The study also provides a cross-cutting analysis of the aggregate impact of ITER spending, in the context of the future EU energy system and EU energy research spending. An analysis of ITER compared to other Big Science projects, especially the Large Hadron Collider at CERN and the European Space Agency (ESA) is provided. This finds that the economic impacts of ITER follow a similar pathway and may deliver a positive net return on investment in future, that there are synergies for firms working across Big Science projects and that F4E can learn lessons on technology transfer and public dissemination and opinion.

Française

Ce rapport présente une analyse des impacts des dépenses faites par F4E sur ITER. Il fournit une analyse détaillée des contributions en nature financées par F4E ainsi qu'une analyse des paiements futurs. En utilisant le modèle économétrique de E3ME, une estimation des impacts sur la VAB et l'emploi a été faite, qui montre que les dépenses d'ITER offrent des avantages significatifs, presque équivalents aux dépenses de F4E. Les impacts des spin-off augmentent encore l'impact économique. Une enquête auprès des entreprises sous-traitantes et une série d'études de cas confirment ces impacts et démontrent les multiples avantages économiques pour les entreprises.

L'étude fournit également une analyse transversale de l'impact global des dépenses d'ITER, dans le contexte du futur système énergétique et des dépenses de recherche énergétique de l'UE. Une analyse d'ITER par rapport à d'autres projets de *Big Science*, en particulier le Grand Collisionneur des Hadrons (CERN) et l'Agence Spatiale Européenne (ESA) est fournie. Cela montre que les impacts économiques d'ITER suivent une trajectoire similaire et peuvent générer un retour sur investissement net positif, des synergies pour les entreprises travaillant sur des projets *Big Science* et que F4E peut tirer des leçons sur le transfert de technologie et la dissémination publique.

Abbreviation List

ASIC	Application Specific Integrated Circuit
BA	Broader Approach
CCS	Carbon Capture and Storage
CE	European Conformity
CeBr	Cerium Bromide
CERN	European Organisation for Nuclear Research
CFD	Computational Fluid Dynamics
DA	Domestic Agencies
DEMO	DEMOnstration Power Station
DG ENER	European Commission Directorate-General for Energy
DG RTD	European Commission Directorate-General for Research and Development
E3ME	Energy-Environment-Economy Global Macro-economic Model
EB	Electro Beam
EC	European Commission
EFDA	European Fusion Development Agreement
EMBL	European Molecular Biology Laboratory
ESA	European Space Agency
ESO	European Southern Observatory
ESRF	European Synchrotron Radiation Facility
ESS	European Spallation Source
EU	European Union
EUR	Euros
EVEDA/IFMIF	Engineering Validation and Engineering Design Activities for the International Fusion Materials Irradiation Facility
F4E	Fusion for Energy (www.fusionforenergy.europa.eu)
FBR	Fast Breeder Reactor
GRT	An F4E coding for Grant funding
GVA	Gross Value Added
GW	Gigawatt
ICF	Inertial Confinement Fusion
IFERC	International Fusion Energy Research Centre
ILL	Institut Laue-Langevin
ILO	Industrial Liaison Officers
ILW	Intermediate Level Waste
IP	Intellectual Property
ISS	International Space Station
ITER	International Thermonuclear Experimental Reactor (www.iter.org)
ITER IO	The ITER Organisation
IR	Infrared
IUA	ITER Unit of Account
IVVS	In-Vessel Viewing System
JET	Joint European Torus
JRC	The Joint Research Centre (of the European Union)
KIT	Karlsruhe Institute for Technology

KPI	Key Performance Indicator
LHC	Large Hadron Collider
LTCC	Low Temperature co-fired ceramic
MFF	Multiannual Financial Framework
MPD	Multi-Purpose Deployer
MRI	Magnetic Resonance Imaging
MS	Microsoft
MW	Megawatt
MYRRHA	Multi-purpose hYbrid Research Reactor for High-tech Applications
NACE	The statistical classification of economic activities in the European Union
NBI	Neutral Beam Injectors
NMR	Nuclear Magnetic Resonance
NPV	Net Present Value
OPE	An F4E coding for Operational expenditures
PET	Positron Emission Tomography
PF	Poloidal Field
PRIMES	Page 15
PV	Photo-Voltaic
QA	Quality Assurance
R&D	Research and Development
RH	Remote Handling
RHCOP	Remote handling Code Of Practice
ROViR	Remote Operation and Virtual Reality Centre
SCK•CEN	Belgium Nuclear Research Centre
SET-Plan	Strategic Energy Technology Plan
SME	Small and Medium Enterprises
STP	Satellite Tokamak Programme
TF	Toroidal Field
TRL	Technology Readiness Level
TUT	Tampere University of Technology
UV	Ultraviolet
VNS	Veolia Nuclear Solutions
VV	Vacuum Vessel
WBS	Work Breakdown Structure
WP	Work Package
XFEL	European X-Ray Free-Electron Laser

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Executive Summary

In this summary we begin with the key conclusions before providing more in-depth summaries of this study and the results.

Key conclusions

Based on the analysis we can draw the following conclusions on the impact of ITER to date and in future.

- **F4E spending on ITER is having a significant economic impact.** The results from modelling show that spending on ITER is delivering almost equal returns in increased GVA (almost €4.8 billion increase compared to €5.1 billion spent) in the EU economy. It has also generated around 34 000 job years between 2008-2017. These impacts are expected to increase, along with spending, in the next 5 years. So far, the geographical distribution of impacts largely correspond to the size of an economy, with a weighting towards France as the host country;
- **In comparison to an alternative spending scenario[1] ITER delivers a net benefit to GVA and employment**, these total €586 million, and 1 000 job years over the full 2008-2030 period;
- **The net benefits are also significantly increased by spin-offs and further innovation stimulated by firms working on ITER and developing new technologies and products,** whilst the modelling results are indicative, they suggest that the impacts noted above increase by a further 25-60% or more due to these effects. The case studies (e.g. Bruker, Pro-beam) that can be found in the main report also clearly demonstrate how either spin-offs or applications in new, non-fusion markets can occur and provide significant financial benefits to firms;
- **F4E spending is having significant positive benefits for firms in a variety of areas.** Companies report that their work on ITER is helping them to develop new cutting edge technologies, to improve their production and other processes, to access business opportunities outside of fusion, build synergies and new opportunities and helping the great majority of firms to develop their technical knowledge and skills;
- **The modelled GVA gains show that ITER compares quite favourably on return on investment to other Big Science projects,** based on evidence from other Big Science projects such as CERN and ESA. ITER is generating total gross GVA at almost a €1 to €1 ratio of input to GVA, with this including a multiplier of 2 or more for the indirect and induced GVA and employment impacts of ITER spending, i.e. the total impacts include the direct impact of ITER and an additional 2 or more euros of GVA or job years from the supply chain and other effects;
- **In the medium to longer term there is likely to be a positive return on investment from the EU commitment to ITER.** This is consistent with the economic assessment made here, which shows that there is already close to a 1-to-1 return, the indications given by firms and similar development pathways experienced at ESA and CERN;
- **It remains highly valuable to keep open the ITER fusion power option, as a large scale, low-carbon, clean, low environmental impact energy technology in which Europe can be self-sufficient.** Although fusion power will only play a major role in the energy system post-2050 it is thought by most experts and in the opinion of the authors that is highly valuable to keep

[1] An alternative scenario was modelled in which the same amount of money as spent on ITER was spent on an ‘alternative investment’ which essentially distributed the money in the same geographical proportions as ITER but in proportion to the GVA of the whole economy.

open the ITER fusion power option, as a large scale, low-carbon, clean, low environmental impact, energy technology in which Europe can be self-sufficient. Whilst the risks with the project are high, the potential benefits are also potentially very high for ITER to act as a catalyst for the sustainable energy transition that will be necessary in the coming decades;

- **ITER should be seen as a Big Science project investment rather than energy research.** Whilst the goal is to contribute to the development of a commercial fusion power technology this remains so far into the future that it is not a key driver for ITER, this would rather be a stronger driver for DEMO;
- **Opportunities and synergies with Big Science.** It is possible to learn from other more advanced projects such as ESA and CERN on how to enhance the public profile of the ITER project and to support technology transfer. Specific technological synergies are already identified with ESA and could be further developed.

Recommendations

We were asked to provide recommendations focused on the dissemination and improvement of ITER impacts and suggest the following:

- **Already begin to systematically invest in technology transfer**. The experience from both the LHC at CERN and ESA demonstrates that setting up an effective technology transfer system takes time but is crucial to enhancing the impact of the public investment. It is also important to reduce the chances that EU investments in the technology development result in sustainable economic gains and not (as in the case of Solar PV) that EU money kick-starts the development of the technology but the industrial production and benefits largely occur elsewhere. Further work to examine the best option for such a mechanism for F4E and ITER would be beneficial as the approaches taken by ESA and CERN differ considerably and each have particular strengths. Steps should be undertaken as soon as possible to build up a technology transfer system, so that it can support innovation and guarantee the continued generation of societal benefits at ITER through its operational phase.
- **Develop a strategy to create a positive public image of ITER and fusion energy.** It is very important to create a positive public image of fusion energy for the future success of the project. This is something that other Big Science projects such as CERN and ESA have managed to achieve and which helps in budget discussions. ITER and F4E should plan more clearly what it will do to engage the public in this way. In our view, important routes for doing so are:
    - Be clear about the time horizon for ITER as only being able to deliver a substantial contribution to the energy system post-2050. Position fusion as much as possible as a big science project that contributes to fundamental human knowledge next to already delivering concrete spin-offs and benefits to society;
    - Position fusion as a fossil-free (baseload) energy source complementary to, not a competitor with, already existing intermittent renewable energy sources such as solar PV and wind;
    - Be as open as possible about benefits and real and perceived risks of the technology;
    - Dedicate substantial budget to inform the public about fusion energy, not only developing dissemination fact sheets, but also engaging and organizing public debate that discusses potential risks and drawbacks, organizing site visits etc.
- **Position fusion energy as clearly as possible in a post-2050 energy system, stressing its benefits in complementing renewables, its environmental benefits and reduction in energy**

dependence. Although there remain considerable uncertainties in what a post-2050 energy system will look like it remains important to position fusion energy within this.

Introduction and approach

Fusion energy has the potential to have a significant impact on the global energy system in future but it is still at an early stage in its development. ITER represents the main international effort to take fusion energy forward and to prove the scientific and technical concept as a stepping stone towards demonstration plants and possible commercial power production. As a multi-billion euro, multi-country international project which is attempting to build a first-of-a-kind device, labelled 'the most complex machine ever built' the ITER project has a high profile and therefore generates interest from the public and policy makers. Not only to account for value for money but also to better understand the opportunities and challenges of the project. Given the early stage in fusion development it is best regarded as a Big Science project, therefore comparators such as the Large Hadron Collider (LHC) at CERN or the European Space Agency (ESA) are useful to learn from and also where potential synergies can be made.

This study is intended to be used as a communication tool for policy makers, industry representatives and the general public, as well as input for the mid-term review of F4E and, crucially, to support further funding requests under the Multiannual Financial Framework to be prepared by the European Commission in 2017.

This work had three key objectives:

1. To establish a robust data set on ITER and BA-related contracting in F4E Member States;
2. To produce an evaluation of the economic impact of these contracts; and
3. To put the aggregate economic impacts in context, and create evidenced-based information and fact-sheets for dissemination purposes.

The approach to this work was based on desk review of a contract and payment database shared by F4E, desk review of other key documents, preparation of dataset of all payments made by F4E and forecast to be made by 2035, econometric modelling of the dataset outputs using the E3ME model to estimate economic impacts. In addition to these desk-based elements a beneficiary survey of companies contracted by F4E (answered by 83 firms or around 30% of firms that were contacted), company case studies and a series of expert interviews were carried out to bolster and validate the results, and to broaden the context of the analysis.

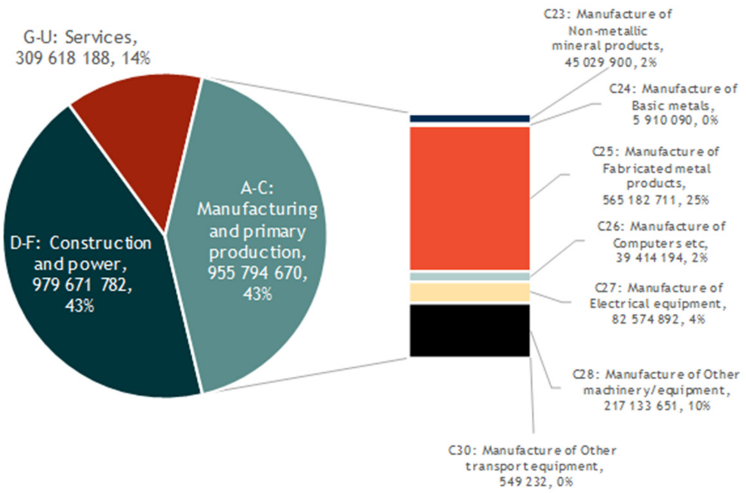
ITER payments to date

Up to mid-2017 around €2.25 billion has been paid out by F4E for the European in-kind contributions to ITER[2]. This spending has found its way to hundreds of different contractors and many more sub-contractors in the EU and globally, with a significant share concentrating in France as host nation[3]. The spending addresses many different work packages of the project, from the magnets, to the vacuum vessel and remote handling. Work on ITER requires a variety of different firms with different skills, but is most heavily split between construction and manufacturing firms, each receiving around 43% of

[2] Also Broader Approach and EFDA contracts related to ITER were analysed and are included in this total, but these were a small subset of the total spending. It should be noted that more work has been contracted, the total value (including that already paid) is closer to €4 billion, but is not yet paid.
[3] France also contributes a much higher share to F4E spending than other EU countries.

payments to date, totalling almost €1 billion euros. The remainder of the spending on services supports technical professionals in architecture, engineering, design and R&D. In the period 2008-2017 there is also a further €2.8 billion spent by F4E or the EC on ITER, this is not included in the figure below as the payment are largely for administration and cash to the ITER Organisation. Further information on the modelled spending can be found in chapter 2 of the main report.

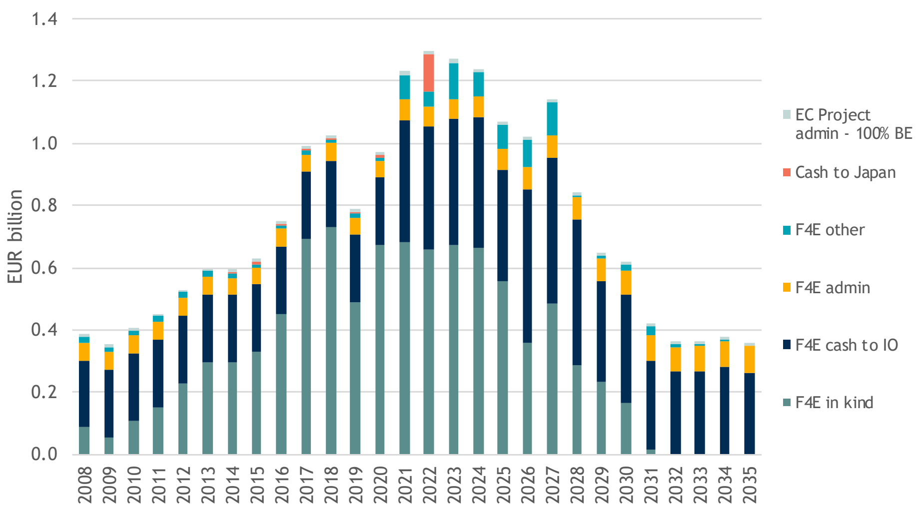
Figure 0-1: Split of F4E payments for the ITER project by economic sector of the recipient



Future ITER payments

This work has modelled the economic impact not only of the EU in-kind contributions to ITER but also the impact of all other EU spending by F4E including cash contributions to the ITER Organisation, other F4E spending, F4E admin spending (primarily on the offices and staff in Barcelona and on site), the EC admin spending and cash to Japan (as part of the Broader Approach). Values for these have been derived from the EC communication[4]. The work considered payments over the 2008-2035 period. The following figure 0-2 provides a summary of these payments over time, the in-kind payments from 2008-2017 match those included in Figure 0-1 above.

Figure 0-2: Summary of estimated annual spending on ITER in EU28



[4] EC COM (2017) 319 Final, EU contribution to a reformed ITER project, plus the accompanying Staff Working Document

Impact of ITER

Table 0-1 presents an overview of the main economic effects emerging from the implementation of F4E contracts, in summary:

- Firstly, the spending on ITER by F4E is having significant positive economic impacts compared to no spending, with 34 000 job years created and almost €4.8 billion in GVA to date;
- Secondly, indicative modelling analysis of the benefits of spin-offs suggests that these would increase gross benefits around 10-20% in each case, but most importantly they deliver significant net benefits, adding a further €78 million in GVA (+59%) and 1 400 job years (+24%) between 2008-2017;
- For the majority of contracted parties, implementing F4E contracts is seen as part of their core business through which they aim to make a profit, some also see an F4E contract as a stepping stone towards realising longer term spin-offs and benefits;
- Among the key reasons for carrying out work on ITER is to boost a firms reputation as a leading high-tech company. Many firms have a positive appraisal of the indirect benefits outside of fusion and big science and which they judge as having good potential for future growth;
- Thirdly, more than 1/3 of firms have developed new cutting edge technologies as a result of their work on ITER. Whilst only a handful of these have led to specific spin-offs this is a longer term process, and one could expect that these benefits will become more visible in future;
- Around ¼ of firms that were surveyed reported that the work has helped them to access new business opportunities both inside and outside fusion. In this area the role of consortiums is important, with many of firms reporting synergies and new opportunities resulting from this. In addition firms had a positive view on synergies in working on other Big Science projects as a result of their work on ITER;
- Finally, 85% of surveyed firms noted that working on ITER had required them to develop new knowledge and skills, with 25% substantially developing their knowledge and skills. The areas of engineering, and engineering and mechanical design were the most common areas for new developments.

Table 0-1: Dashboard impact indicators for GVA and employment - gross impacts (compared to no alternative spending) only

Theme/ area	Proposed indicator	Summary impact to date	Estimated impact to 2030
Employment and growth in EU28	Value added (GVA) contribution	**Cumulative 2008-2017:** €4 786 million **2017 only:** €1 104 million **Potential additional benefit from spinoffs 2008-2017:** €561 million	**Cumulative 2018-2030:** €15 900 million **2030 only:** €795 million **Potential additional benefit from spinoffs 2018-2030:** €2 248 million
	Employment contribution	**Cumulative 2008-2017:** 34 000 job years **2017 only:** 7 400 job years **Potential additional benefit from spinoffs 2008-2017:** 4 700 job years	**Cumulative 2018-2030:** 72 400 job years **2030 only:** 2 800 job years **Potential additional benefit from spinoffs 2018-2030:** 10 900 job years

ITER impacts in context of EU policy and spending

Aggregate economic impacts

As noted in Table 0-1 the ITER project is having significant economic impact already, generating GVA practically equivalent to the money spent, and even more when spin-off effects are modelled. In future it is expected that these impacts will increase in line with spending as the remaining €13.7 billion of the planned EU commitment is spent over the next 17 years. In total this is expected to deliver gross **extra GVA of €15.9 billion and 72 400 job years between 2018-2030**.

Impacts in context

In the context of EU energy policy this is established only until 2050, by which time the energy system should already be largely decarbonised to meet climate mitigation goals. Whilst the low-carbon nature of fusion is one of a number of key attributes of the technology it is also the case that fusion energy will not be able to deliver power at any kind of scale until after 2050. ITER impacts now are most comparable to renewable energy research on technologies at similar stages of development, yet for wind and solar this stage was experienced 40-50 years ago, with the successful development being experienced at scale only in recent years. Analysis on such early steps and their impacts is very limited, therefore a better comparison can be made with other Big Science projects. The energy system impact of ITER and fusion will come during the subsequent DEMO stage.

Whilst ITER funding is not inconsequential it remains only a relatively small part of the overall EU budget. A part which is delivering significant economic impacts now with the potential for much more in future.

Comparisons and synergies with Big Science

Along with ESA and CERN, ITER is one of the three top Big Science project organizations in the EU and among the leading ongoing Big Science projects globally. The experience with ESA and CERN is that they deliver a positive return on investment in the medium-long term. For ITER, the positive economic indicators at this relatively early stage bodes well for expecting similar positive net returns in future.

The types of technologies being developed for ITER have links to those also being developed for CERN and ESA, this provides opportunities for synergies between these projects. Opportunities for these synergies with ESA have already been identified through joint discussions between ESA and F4E. The synergies are also applicable for firms that work on Big Science as the network and process enables easier connection to business opportunities in ITER or other Big Science projects.

ESA and CERN both offer aspects from which ITER can learn, particularly in the areas of technology transfer and public engagement and dissemination strategies. The contrasting but successful approaches to technology transfer used by both ESA and CERN offer a template for ITER for which planning could already begin.

Résumé Analytique

Dans ce résumé, nous commençons par les conclusions clés avant de fournir des résumés plus détaillés de cette étude et des résultats.

Conclusions Principales

Sur la base de l'analyse, nous pouvons tirer les conclusions suivantes sur l'impact d'ITER à ce jour et à l'avenir.

- **Les dépenses de F4E sur ITER ont un impact économique significatif**. Les résultats de la modélisation économétrique montrent que les dépenses pour ITER donnent des rendements presque égaux en augmentation de la VAB (près de 4,8 milliards d'euros d'augmentation par rapport à 5,1 milliards d'euros dépensés) dans l'économie de l'UE. Il a également généré environ 34 000 années de travail entre 2008 et 2017. Ces impacts devraient augmenter, ainsi que les dépenses, au cours des cinq prochaines années. Jusqu'à présent, la répartition géographique des impacts correspond largement à la taille de l'économie, avec une pondération vers la France en tant que pays d'accueil;
- **Par rapport à un scénario de dépenses alternatif[5], ITER apporte un bénéfice net à la VAB et à l'emploi**, à savoir 586 millions d'euros et 1 000 années de travail (job years) sur l'ensemble de la période 2008-2030;
- **Les bénéfices nets sont également significativement accrus par les spin-off et l'innovation stimulée par les entreprises travaillant sur ITER et le développement de nouvelles technologies et produits**, alors que les résultats de modélisation économétrique sont indicatifs, suggèrent que les impacts mentionnés ci-dessus augmentent de 25% à 60% ou plus en raison de ces effets. Les études de cas (par exemple Bruker, Pro-beam) qui peuvent être trouver dans le rapport principal montrent clairement comment les spin-off ou les applications peuvent se produire sur de nouveaux marchés différents de celui de la fusion et apporter des avantages financiers significatifs aux entreprises;
- **Les dépenses de F4E ont des retombées positives importantes pour les entreprises dans divers domaines.** Les entreprises déclarent que leur travail sur ITER les aide à développer des nouvelles technologies de pointe, améliorer leur production et d'autres processus, accéder à des opportunités commerciales en dehors de la fusion, créer des synergies et de nouvelles opportunités et aider la grande majorité des entreprises à développer leurs connaissances et compétences techniques;
- **Les gains modélisés de la VAB montrent qu'ITER se compare plutôt favorablement au retour sur investissement par rapport les autres projets de *Big Science***, sur la base des preuves provenant d'autres projets Big Science tels que le CERN et l'ESA. ITER génère une VAB totale d'un ratio d'intrants de près de 1 € à 1 €, avec un multiplicateur de 2 ou plus pour les impacts indirects et induits de la VAB et de l'emploi des dépenses ITER. Les impacts totaux incluent l'impact direct d'ITER et de 2 ou plusieurs euros supplémentaires de VAB ou d'années d'emploi de la chaîne d'approvisionnement et d'autres effets;

[5] Un scénario alternatif a été modélisé dans lequel le même montant qu'a été dépensé pour ITER était dépensé pour un « investissement alternatif » qui distribuait essentiellement l'argent dans les mêmes proportions géographiques qu'ITER mais proportionnellement à la VAB de l'ensemble de l'économie.

- **À moyen et long terme, l'engagement de l'UE envers ITER devrait générer un retour sur investissement positif**. Ceci est cohérent avec l'évaluation économique faite ici, qui montre qu'il y a déjà près d'un retour 1-à-1, les indications données par les entreprises et les voies de développement similaires suivis par l'ESA et au CERN;
- **Il reste très important de garder une option ouverte sur l'énergie de fusion d'ITER, en tant que technologie énergétique à grande échelle, sobre en carbone, propre et à faible impact environnemental, dans laquelle l'Europe peut être autosuffisante**. Bien que la puissance de fusion ne joue un rôle majeur dans le système énergétique qu'après 2050, la plupart des experts estiment que cette option est très utile pour maintenir l'option ouverte d'énergie de fusion ITER, à grande échelle et à faible émission de carbone. Une technologie énergétique propre, à faible impact environnemental, dans laquelle l'Europe peut être autosuffisante. Bien que les risques liés au projet soient élevés, les retombées potentielles sont également très importantes pour qu'ITER joue un rôle de catalyseur dans la transition énergétique durable qui sera nécessaire dans les décennies à venir;
- **ITER devrait être considéré comme un investissement de projet *Big Science* plutôt qu'une recherche énergétique**. Alors que le but est de contribuer au développement d'une technologie d'énergie de fusion commerciale, cela reste tellement loin dans le futur que ce n'est pas le but principal pour ITER, ce serait plutôt un conducteur plus fort pour le réacteur DEMO;
- **Opportunités et synergies avec *Big Science***. Il est possible d'apprendre d'autres projets plus avancés tels que l'ESA et le CERN sur la façon d'améliorer le profil public du projet ITER et de soutenir le transfert de technologie. Des synergies technologiques spécifiques sont déjà identifiées avec l'ESA et pourraient être développées plus avant.

Recommandations

Nous avons été invités à formuler des recommandations ciblées sur la diffusion et l'amélioration des impacts d'ITER et à mettre en avant les éléments suivants :

- **Commencer dès maintenant à investir systématiquement dans le transfert de technologie**. L'expérience du Grand Collisionneur de Hadrons (LHC) au CERN et de l'ESA montre que la mise en place d'un système efficace de transfert de technologie prend du temps mais est cruciale pour renforcer l'impact de l'investissement public. Il est également important de réduire les chances que les investissements de l'UE dans le développement technologique aboutissent à des gains économiques durables et non (comme dans le cas du PV solaire) que l'argent de l'UE stimule le développement de la technologie mais les gains et l'activité industrielle se réalisent d'autre part. Des travaux visant à examiner la meilleure option pour un tel mécanisme pour F4E et ITER seraient bénéfiques car les approches adoptées par l'ESA et le CERN diffèrent considérablement et ont chacune leurs points forts. Des mesures devraient être prises dès que possible pour mettre en place un système de transfert de technologie, afin qu'il puisse soutenir l'innovation et garantir la génération continue de bénéfices sociétaux à ITER pendant sa phase opérationnelle;
- **Développer une stratégie pour créer une image publique positive d'ITER et de l'énergie de fusion.** Il est très important de créer une image publique positive de l'énergie de fusion pour le succès futur du projet. C'est quelque chose que d'autres grands projets scientifiques tels que le CERN et l'ESA ont réussi à réaliser et qui contribuent aux discussions budgétaires. ITER et F4E devraient planifier plus clairement ce qu'il fera pour engager le public de cette manière. À notre avis, les voies importantes pour le faire sont les suivantes :

    - Soyez clair sur l'horizon temporel pour qu'ITER ne puisse apporter une contribution substantielle au système énergétique qu'après 2050. Positionner la fusion autant que possible comme un grand projet scientifique qui contribue à la connaissance humaine fondamentale en plus de fournir déjà des retombées concrètes et avantages pour la société;
    - Positionner la fusion comme une source d'énergie sans hydrocarbures (source d'énergie de base) complémentaire à, et non un concurrent, des sources d'énergie renouvelables intermittentes déjà existantes telles que le PV solaire et le vent;
    - Soyez tant ouvert que possible sur les avantages et les risques réels et perçus de la technologie;
    - Consacrer un budget substantiel pour informer le public sur l'énergie de fusion, non seulement en développant des fiches de diffusion, mais aussi en engageant et en organisant un débat public sur les risques et les inconvénients potentiels, en organisant des visites de sites, etc.
- **Positionner l'énergie de fusion ainsi clairement que possible dans un système énergétique post-2050, en soulignant ses avantages environnementaux, en complémentant les énergies renouvelables et la réduction de la dépendance énergétique**. Bien qu'il subsiste des incertitudes considérables sur ce à quoi ressemblera un système énergétique post-2050, il reste important de positionner l'énergie de fusion à l'intérieur de celle-ci.

Introduction et approche

L'énergie de fusion a le potentiel d'avoir un impact significatif sur le système énergétique mondial à l'avenir, mais elle est encore à un stade précoce de son développement. ITER représente l'effort principal international pour faire avancer l'énergie de fusion et pour prouver le concept scientifique et technique comme un tremplin vers les usines de démonstration et la production d'énergie commerciale possible. En tant que projet international de plusieurs pays et d'une valeur de plusieurs milliards d'euros qui tente de construire un appareil unique en son genre, présenté comme «la machine la plus complexe jamais construite », le projet ITER jouit d'une grande visibilité et suscite l'intérêt du public et les décideurs politiques. Non seulement pour rendre compte de l'optimisation des ressources, mais aussi pour mieux comprendre les opportunités et les défis du projet. Étant donné le stade précoce du développement de la fusion, il est préférable de le considérer comme un projet de *Big Science*. Il est donc utile d'utiliser des projets similaires tels que le Grand Collisionneur de Hadrons (LHC), CERN ou l'Agence Spatiale Européenne (ESA) d'évaluer les synergies potentielles.

Cette étude est destinée à être utilisée comme un outil de communication pour les décideurs politiques, les représentants de l'industrie et le grand public, ainsi que pour la revue à mi-parcours de F4E et, surtout, pour soutenir les demandes de financement au titre du Cadre Financier Pluriannuel, préparé par la Commission Européenne en 2017.

Ce travail avait trois objectifs clés :

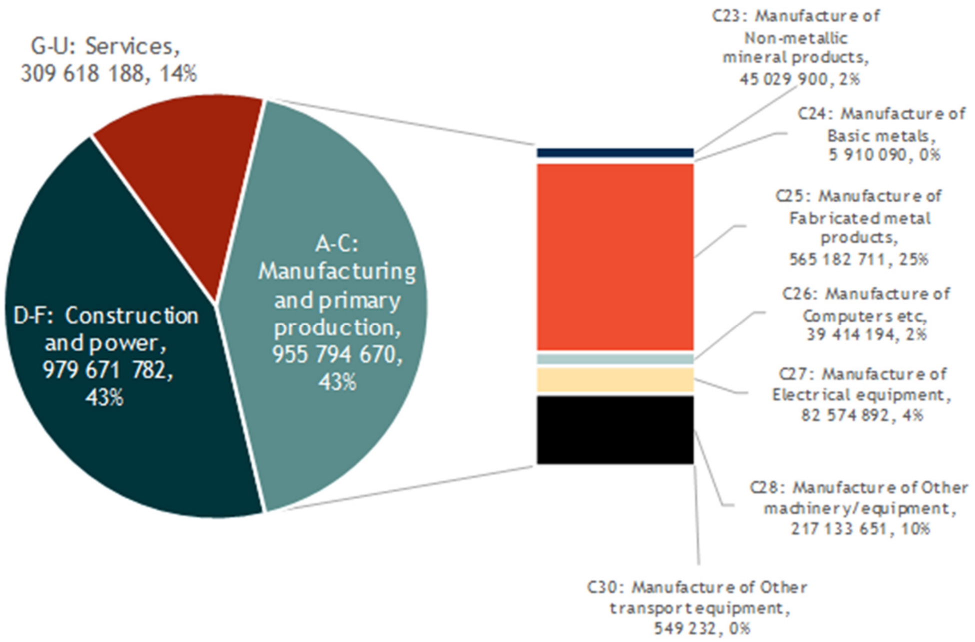
1. Établir une base de données solide sur les contrats ITER et BA dans les États membres de F4E ;
2. Produire une évaluation de l'impact économique de ces contrats ; et
3. Mettre en contexte les impacts économiques globaux et créer des informations factuelles et des fiches factuelles à des fins de diffusion.

L'approche de ce travail était basée sur l'examen documentaire d'une base de données de contrat et de paiement partagée par F4E, l'examen documentaire d'autres documents clés, la préparation de l'ensemble de données de tous les paiements effectués par F4E et les prévisions pour 2035, modélisation économétrique des données utiliser dans le modèle développé par E3ME pour estimer les impacts économiques. En plus de ces éléments documentaires, une enquête auprès des bénéficiaires des entreprises contractées par F4E (réponse de 83 entreprises ou environ 30% des entreprises contactées), des études de cas d'entreprises et une série d'entretiens d'experts ont été menées pour valider les résultats et d'élargir le contexte de l'analyse.

Paiements ITER à ce jour

Jusqu'au mi-2017, environ 2,25 milliards d'euros ont été versés par F4E pour les contributions européennes à destination d'ITER[6]. Ces dépenses ont trouvé leur chemin vers des centaines d'entreprises différents et beaucoup plus de sous-traitants dans l'UE et dans le monde, avec une part importante concentrée en France en tant que pays hôte.[7] Les dépenses concernent de nombreux lots de travaux du projet, allant des aimants au chambres à vide et à la télémanipulation. Les travaux sur ITER nécessitent une variété de firmes avec des compétences différentes, mais sont plus fortement répartis entre les entreprises de construction et de fabrication, chacune recevant environ 43% des paiements à ce jour, correspondant de près de 1 milliard d'euros. Le reste des dépenses consacrées aux services soutient les professionnels de l'architecture, de l'ingénierie, du design et de la recherche et développement. Au cours de la période 2008-2017, F4E ou la CE a également dépensé 2,8 milliards d'euros sur ITER, ce qui n'est pas inclus dans la figure ci-dessous car les paiements sont principalement destinés à l'administration et à l'organisation de gestion d'ITER. Information plus détaillée sur les dépenses modélisées est disponibles au chapitre 2 du rapport principal.

Figure 0-1: Répartition des paiements de F4E pour le projet ITER par secteur économique du bénéficiaire



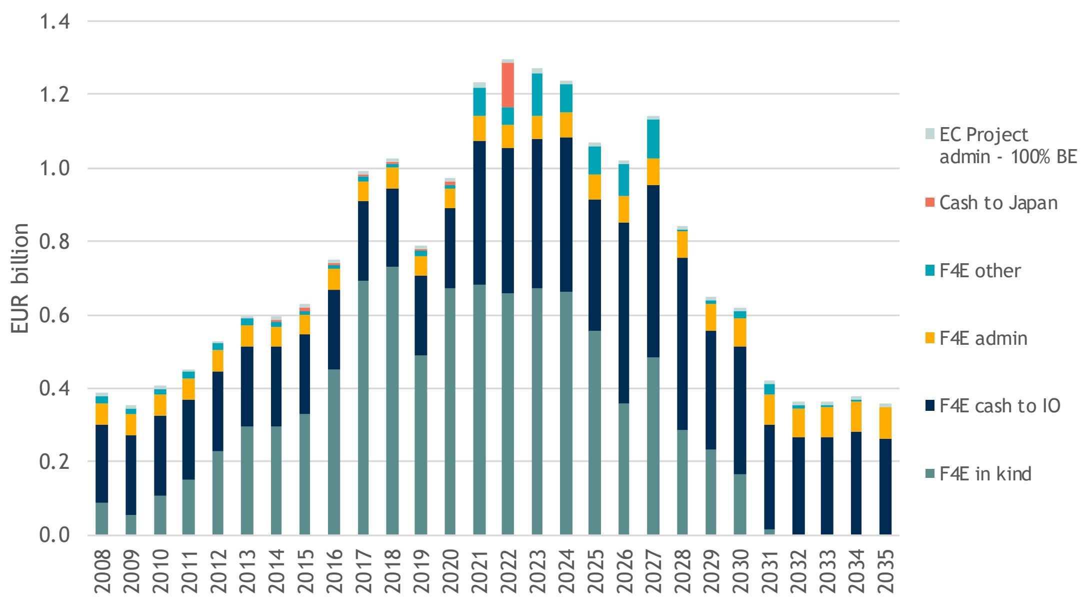
[6] Les contrats de l'approche élargie et de l'EFDA relatifs à ITER ont également été analysés et sont inclus dans ce rapport, mais il s'agissait d'un petit sous-ensemble des dépenses totales. Il faut noter que davantage de travail a été contracté, la valeur totale (y compris celle déjà payée) est plus proche de 4 milliards d'euros, mais n'est pas encore payée.

[7] La France contribue également beaucoup plus aux dépenses F4E que les autres pays de l'UE.

Futurs paiements ITER

Ce travail a modélisé l'impact économique non seulement des contributions en nature de l'UE à ITER, mais aussi de toutes les autres dépenses faites de part de l'UE par F4E, y compris les contributions en espèces à l'organisation d'ITER, les autres dépenses de F4E pour le personnel en Barcelone et sur place en Cadarache, France, les dépenses de l'administration communautaire et les transferts monétaires au Japon (dans le cadre de l'approche élargie(BA)). Les valeurs pour celles-ci ont été dérivées de la communication de la CE[8]. Le travail a pris en compte les paiements sur la période 2008-2035. La Figure suivante 0-2 fournit un résumé de ces paiements au fil du temps, les paiements en nature de 2008-2017 correspondent à ceux de la Figure 0-1 ci-dessus.

Figure 0-2: Résumé des dépenses annuelles estimées pour ITER dans l'UE28



Impact d'ITER

Le tableau 0-1 présente un aperçu des principaux effets économiques de la mise en œuvre des contrats F4E, en résumé:

- Les dépenses d'ITER par F4E ont des retombées économiques positives importantes par rapport à l'absence de dépenses, avec 34 000 années de travail créés et près de 4,8 milliards d'euros de VAB à ce jour;
- L'analyse de modélisation indicative des avantages des entreprises de spin-off suggère que celles-ci augmenteraient les bénéfices bruts autour de 10-20% dans chaque cas, mais surtout, elles produiraient des bénéfices nets significatifs, ajoutant 78 millions d'euros de VAB (+ 59%) et 1 400 années d'emploi (+24%) entre 2008 et 2017;
- Pour la majorité des parties contractantes, la mise en œuvre des contrats F4E est considérée comme faisant partie de leur cœur de métier à travers lequel ils visent à réaliser des bénéfices, certains considèrent également un contrat F4E comme un tremplin vers la réalisation divers des spin-off et aux avantages à plus long terme;
- Parmi les principales raisons d'effectuer des travaux sur ITER figure la promotion de la réputation des entreprises en tant que leader de la haute technologie. De nombreuses

[8] CE COM (2017) 319 final, contribution de l'UE à un projet ITER réformé, ainsi que le document de travail des services

entreprises ont une appréciation positive des avantages indirects en dehors de la fusion et de *Big Science* et les jugent comme ayant un bon potentiel de croissance future;

- Plus d'un tiers des entreprises ont développé des nouvelles technologies de pointe grâce à leur travail sur ITER. Si seulement une d'entre elles conduit à des spin-off spécifiques, il s'agit d'un processus à plus long terme, et l'on pourrait s'attendre à ce que ces avantages deviennent plus visibles à l'avenir;
- Environ un quart des entreprises interrogées ont indiqué que le travail les avait aidées à accéder à de nouvelles opportunités d'affaires à l'intérieur et à l'extérieur de marché de fusion. Dans ce domaine, le rôle des consortiums est important, de nombreuses entreprises signalent des synergies et de nouvelles opportunités comme résultat. En outre, les entreprises avaient une vision positive des synergies dans le travail sur d'autres projets *Big Science* grâce à leurs travaux sur ITER;
- 85% des entreprises interrogées ont noté que travailler sur ITER leur avait demandé de développer de nouvelles connaissances et compétences, 25% d'entre elles développant substantiellement leurs connaissances et leurs compétences. Les domaines de l'ingénierie, de l'ingénierie et de la conception mécanique étaient les domaines les plus courants pour les nouveaux développements.

Tableau 0-1 : Indicateurs d'impact pour la VAB et l'emploi - impacts bruts (par rapport à l'absence de dépenses alternatives)

Thème / zone	Indicateur proposé	Impact résumé à ce jour	Incidence estimée jusqu'en 2030
Emploi et croissance dans EU28	Contribution à valeur ajoutée (VAB)	**Cumulatif 2008-2017 :** €4 786 million **2017 seulement :** €1 104 million **Bénéfice additionnel potentiel des spin-off 2008-2017:** €561 million	**Cumulatif 2018-2030 :** €15 900 million **2030 seulement :** €795 million **Bénéfice additionnel potentiel des spin-off 2018-2030:** €2 248 million
	Contribution à l'emploi	**Cumulatif 2008-2017 :** 34 000 années de travail **2017 seulement :** 7 400 années de travail **Bénéfice additionnel potentiel des spin-off 2008-2017:** 4 700 années de travail	**Cumulatif 2018-2030 :** 72 400 années de travail **2030 seulement :** 2 800 années de travail **Bénéfice additionnel potentiel des spin-off 2018-2030:** 10 900 années de travail

Les impacts d'ITER dans le contexte de la politique et des dépenses de l'UE

Impacts économiques globaux

Comme indiqué dans le Tableau 0-1, le projet ITER a déjà un impact économique significatif, générant une VAB pratiquement équivalente à l'argent dépensé, et encore plus lorsque les effets secondaires sont modélisés. À l'avenir, il est estimé que ces impacts augmentent parallèlement aux dépenses, les 13,7 milliards d'euros restants de l'engagement de l'UE prévu étant dépensés au cours des 17 prochaines années. Au total, cela devrait générer une **VAB supplémentaire brute de 15,9 milliards d'euros et 72 400 années de travail entre 2018-2030.**

Impacts dans le contexte

Dans le contexte de la politique énergétique de l'UE, cela n'est établi que jusqu'en 2050, date à laquelle le système énergétique devrait déjà être largement décarboné pour atteindre les objectifs d'atténuation du changement climatique. Alors que la nature à faible teneur en carbone de la fusion est l'un des nombreux attributs clés de la technologie, l'énergie de fusion ne sera pas capable de fournir de l'énergie à n'importe quelle échelle avant 2050. Les impacts d'ITER sont maintenant comparables à recherche sur les énergies renouvelables sur des technologies à des stades similaires de développement, mais pour le vent et le solaire, cette étape a été expérimentée il y a 40-50 ans, et le développement réussi n'a été expérimenté à grande échelle que ces dernières années. L'analyse de ces étapes précoces et de leurs impacts est très limitée, donc une meilleure comparaison peut être faite avec d'autres projets *Big Science*. L'impact du système énergétique d'ITER et de la fusion viendra au cours du stade DEMO suivant.

Si le financement d'ITER n'est pas sans conséquence, il ne représente qu'une part relativement faible du budget global de l'UE. Une partie qui produit des retombées économiques significatives maintenant avec le potentiel pour beaucoup plus à l'avenir.

Comparaisons et synergies avec Big Science

Avec l'ESA et le CERN, ITER est l'une des trois principales organisations de projets *Big Science* dans l'UE et l'un des principaux projets en cours dans le domaine des *Big Science* à l'échelle mondiale. L'expérience avec l'ESA et le CERN est qu'ils offrent un retour sur investissement positif à moyen et long terme. Pour ITER, les indicateurs économiques positifs à ce stade relativement précoce sont de bon augure pour anticiper des rendements nets positifs similaires à l'avenir.

Les types de technologies développées pour ITER ont des liens avec ceux qui sont en cours de développement pour le CERN et l'ESA, ce qui offre des opportunités de synergies entre ces projets. Des opportunités pour ces synergies avec l'ESA ont déjà été identifiées grâce à des discussions conjointes entre l'ESA et F4E. Les synergies sont également applicables pour les entreprises qui travaillent sur Big Science car le réseau et le processus permet une connexion plus facile aux opportunités d'affaires dans ITER ou d'autres projets *Big Science*.

L'ESA et le CERN offrent tous deux des aspects sur lesquels ITER peut apprendre, en particulier dans les domaines du transfert de technologie, de l'engagement du public et des stratégies de diffusion. Les approches contrastées mais réussi du transfert de technologie utilisées à la fois par l'ESA et le CERN offrent un modèle pour ITER pour lequel la planification pourrait déjà commencer.

1. Introduction

1.1. Research context and objectives

1.1.1. The societal relevance – Fusion energy could provide a very important contribution to addressing long-term climate and energy challenges

The international energy sector currently faces one of its most important challenges ever: to become largely carbon-neutral by 2050 and maintain this position thereafter, while at the same time providing energy to an increasing global population that – particularly in developing countries – is also likely to use more energy per person in the decades to come. Many new technologies and innovations are needed to face this challenge, each with their own benefits and drawbacks.

In the long term (to 2100), nuclear fusion can provide an important contribution to a future carbon-neutral energy sector, as it can potentially provide abundant energy without emitting greenhouse gases nor other air pollutants. In addition, as a high-tech sector it can provide spin-offs in many fields, from advanced materials to construction and service industries. Europe is currently at the forefront of the development of this technology, not only hosting the under construction ITER facility, but also providing the largest contribution to the international consortium that is currently developing the technology.

ITER is one of the most challenging projects mankind has ever undertaken. It is pushing the limits of science and technology in many fields, from high-field superconducting magnets to large-volume vacuum systems, cryoplants, precision-machined heat resistant materials and nuclear technology, to advanced control systems and computational models of plasma turbulence. It is often called 'the most complex device' on earth and is the biggest international project currently in development. These challenges force companies to invention, product development and quality assurance of the highest order. ITER therefore is thought to lead to innovation and increased competitiveness for the industries that participate in it.

1.1.2. For the time being, ITER is a Big Science project and should be assessed as such

Nuclear fusion is not yet at the stage where it can provide a commercial contribution to the international energy sector and it will not be able to do so until at least 2050, when the EU economy should be largely carbon neutral if policy goals of 80-95% reductions in emissions are met. Continued and further investments will be required to advance the technology and to bring it towards fully-fledged implementation: the ITER project should lead to DEMO in 2055, which should prove the feasibility of large scale electricity production. In the public debate about the sources that will contribute to a future carbon-neutral energy sector, nuclear fusion has to compete with other low-carbon energy sources that are already at the implementation stage and have high public support, such as solar PV and wind energy. Fusion is complementary to these renewable energy technologies, with its greatest potential being in replacing the large fossil fuel and nuclear fission plants that will still play an important (although smaller than now) role in the post-2050 energy system[9].

[9] In the current EU Reference energy scenario (PRIMES, 2016) in 2050 nuclear fission, coal and solid fuels, oil and natural gas will still supply 45% of the power in the EU energy system.

With the above in mind, ITER is best seen as a Big Science project, comparable to the European Organisation for Nuclear Research (CERN) or European Space Agency (ESA), which generates positive effects on its own account, even without the perspective of generating carbon neutral energy more than 30 years from now. In addition to the positive effects resulting from the current and future ITER activities, in the current public and political discussion about the carbon-neutral energy sector in Europe fusion needs to promote its potential benefits and spin-offs as much as possible. These benefits include the wider economic impacts of the ITER project activities in terms of job creation and contribution to Europe's global competitiveness.

1.1.3. Brief historic overview – ITER and the Broader Approach

Fusion energy research and development is primarily concentrated in the ITER programme. The ITER project represents the key international effort and stemmed from an agreement between presidents Reagan and Gorbachev in 1985, from which a collaboration between the Soviet Union (now Russian Federation), United States, the European Union and Japan developed. Later China, India and South-Korea joined the ITER consortium prior to the formal ITER agreement being signed in 2006.

The EU commitment to ITER is the largest of the seven consortium members, with its contributions representing approximately 45% of the resources for ITER, and the site for the reactor in France. The other ITER members provide approximately 9% each.

As the ITER project entered the industrial phase (from 2008), the European Domestic Agency - Fusion for Energy (F4E) was set up in 2007, for a period of 35 years, to provide EU contributions to ITER and the Broader Approach (see below). F4E works with industry and research organisations to do this.

The Broader Approach (BA) is separate but complementary to ITER and is a 50:50 international cooperation between Europe and Japan, with some of the EU Member States providing around €340 million over the first 10 years of the agreement signed in 2007. It was partially the result of the deal that was made to site the ITER reactor in France and involves three substantial fusion research projects being jointly funded in Japan, namely the:

- Satellite Tokamak Programme (STP) project JT-60SA;
- International Fusion Energy Research Centre (IFERC);
- Engineering Validation and Engineering Design Activities for the International Fusion Materials Irradiation Facility (EVEDA/IFMIF).

The EU involvement in ITER fits within the overarching Energy Union strategy for the EU and its objectives of making EU energy supply more secure, affordable and sustainable. The ITER activities could potentially contribute to all three of these goals in the future. Of the five dimensions of the Energy Union, the research, innovation and competitiveness dimension is currently of most importance to ITER, with the key objectives for this defined in the Strategic Energy Technology Plan (SET-Plan).

The SET-Plan has been at the forefront of EU energy technology policy since 2007 and was last updated in 2015. This update set out 10 actions to accelerate reaching the goals of the Energy Union and to support job creation and economic growth. The tenth action focuses on nuclear energy technologies, both fission and fusion, and within which the development of nuclear fusion is highlighted. This is notable for highlighting that fusion is among the priority actions of the EU.

1.1.4. The opportunities and challenges – are not only technical and scientific, but also competitive

There are multiple challenges for fusion energy as a whole and the ITER project specificially, including:

- **The fundamental technical and scientific challenges:** these are the most important to the success of the ITER project, with many of the components for the experimental reactor requiring new science, materials, processes and technology which stretch the limits of current knowledge and ingenuity. Even where components have been successfully tested in existing reactors such as JET the increase in scale can pose significant new problems.

- **The potential success of alternative fusion approaches:** the ITER project is based on the Tokamak design, which to date is the most successful and mature of the various fusion approaches. Of the alternatives, the inertial confinement fusion (ICF) design, based on lasers, is the second most mature, although the major US facility (National Ignition Facility, Lawrence Livermore National Laboratory) leading efforts in this area has seen its work downscaled. It is notable that this work also had a focus on both military and civilian power applications. A range of other research, including major industrial players with other designs are active, e.g. the Wendelstein 7-X Stellerator in Germany (20% EU funded), the ARC concept of MIT and the General Fusion company in Canada. These other programmes are way behind in their development and have received only relatively modest investments compared to ITER. Their driving idea is typically to develop a much smaller fusion reactor in a shorter timeframe than ITER, so far the focus is primarily on the science rather than the multiple technical and technological hurdles that ITER is already working on. This being said, there remains a (relatively small) possibility that if one of these schemes shows much greater promise than the Tokamak design, the political support for ITER will diminish. Although it should also be noted that these other programmes also draw heavily on the science and technology developed for ITER.

- **ITER is only the first of two major steps eventually leading to commercialisation:** the (R&D) roadmap for fusion energy based on the tokamak design envisages ITER as an intermediate step towards DEMO, a demonstration reactor targeted for 2050-2060 which will demonstrate the viability of fusion power. The timescales for this development have slipped significantly and the long timelines require stability in EU and international commitment and funding over a long period, this creates risks and uncertainties. It is crucial for ITER to sustain interest and funding, and also that the DEMO project continues to move forward (initial design phases have already started) so that the outputs of ITER move closer to full utilisation and commercialisation as the major long-term economic opportunity lies in the period 2050-2100.

- **Competition with other power technologies:** as noted above, in the EU the SET-Plan has a focus on multiple low-carbon energy technologies not just fusion, and existing fossil and fission power will still play a role well into the future. Fusion energy is only one of multiple technologies that can form part of the future near-zero emission energy system. Whilst the potential is there for fusion energy to play a major role in this, this is highly unlikely to be possible until well after 2050. In the meantime, there is also the potential for other solutions to be developed that address issues of renewables intermittency or fossil fuel emissions, through improved efficiency, cost reductions, energy conversion, transport and storage, carbon capture and storage (CCS) (or utilisation) or other means. Whilst there may still be a considerable need post 2050 to complement renewable energy technologies and replace the remaining fossil fuel plants, there is no guarantee of a market space for fusion as a potential base-load power to compete with fossils (with CCS) or fission, if it cannot compete with these other technologies on both functionality and cost. As it is not likely that fusion will generate electricity at competitive cost in the foreseeable future, this points to the fact that the unique selling points of fusion, including providing energy independence, the ability to generate electricity on demand at any given moment in time, its relative cleanliness, and unsuitability for nuclear weapons proliferation, should be stressed rather than (only) focusing on cost competitiveness. Energy dependence in 2050 might be still an issue, as the EU reference scenario indicates that EU import dependency in 2050 might increase (to 57.6%) rather than decrease[10], although the largest part of this dependency is anticipated to be oil for transport purposes.

At the same time, there are opportunities:

- **The EU and its industry have a leading role in the ITER project:** by taking responsibility for the largest part of the funding of ITER and having the facility sited in France the EU has a strong position. If this position, built up over 30 years, is fully utilised it can put EU industry at the forefront of the technological development not only of fusion energy but the other industrial applications of the technologies, presenting a significant opportunity for economic growth and competitive advantage. Maintaining this role, and avoiding the considerable resources already invested not being taken advantage of, will require continued policy support and funding, particularly keeping in mind the challenges presented above. It may also require more strategic thinking and planning to avoid the risk that pioneering work is carried out in Europe but that the key industrial activities are eventually carried out elsewhere, as has been the case for Solar PV.

- **The potential advantages of fusion energy are considerable:** as noted above fusion energy potentially has a number of important advantages, these include that the inputs to it are widely available in Europe and globally, so that it would help contribute to energy independence. It is suited to generating electricity on demand at any given moment in time, which can add to energy system stability and complement intermittent renewable energy generation, like wind and solar, much better than other fossil or fission power technologies. Compared to nuclear fission, fusion energy will be much cleaner with very low quantities of radioactive waste expected, and the waste is much less radioactive (much shorter half-lives). In comparison to fission it is also much safer to operate, and the nature of the technology means that the applications are only in civil power generation, not weapons proliferation.

- **Other 'Big Science' projects can provide lessons for ITER:** ITER is a major Big Science project in its own right, but it can also learn important lessons from other large science and industrial projects involving international or European cooperation, such as the Large Hadron Collider at CERN; or the European Space Agency and its various programmes.

1.1.5. The relevance of the assignment

Given the large investment in ITER and the very long lead time to the potential application, policy makers and the general public have a right to be informed about the short-term impact of ITER as well as about the expected mid and long-term impacts.

[10] EC (2016) EU Reference Scenario - Main Results, Brussels

The key benefits of the ITER activities, apart from the long-term perspective of energy generation, are the economic spin-offs of these activities in terms of high (and low)-tech employment in the EU and its contributions to EU international competitiveness. In order to present these benefits in an appropriate, authoritative and convincing way, an underpinning evidence-base is needed. This evidence base should detail the size and nature of the economic spin-offs of ITER to date, as well as give estimates for the future. It should also compare these impacts to other fundamental research projects in the EU and internationally (i.e. the Large Hadron Collider at CERN, the European Space Agency), other possible future energy sources and the energy and economic situation in order to put them into context now and in the future to 2050 and beyond.

1.1.6. The objectives of the study

This study is intended to be used as a communication tool for policy makers, industry representatives and the general public, as well as input for the mid-term review of F4E and, crucially, to support further funding requests under the Multiannual Financial Framework (MFF) to be prepared by the European Commission in 2018.

This work has three key objectives:

1. To establish a robust data set on ITER and BA-related contracting in F4E Member States;
2. To produce an evaluation of the economic impact of these contracts; and
3. To put the aggregate economic impacts in context and create evidence-based information and fact-sheets for dissemination purposes.

1.2. Methodology and Approach

The overall approach to this work is based around 3 tasks, the following section briefly describes the approach taken to each task.

1.2.1. Task 1: Creation of the dataset

Overview

Task 1 establishes a robust dataset on payments related to ITER and BA -related contracting in F4E Member States. The output of this task forms a useful deliverable in its own right and is the basis for work in task 2. The dataset is an MS Excel file including relevant contracting activities and appropriate analytical support with the use of graphs, charts and maps. Please see chapter 2 for summary extracts and analysis from the dataset.

Specifics

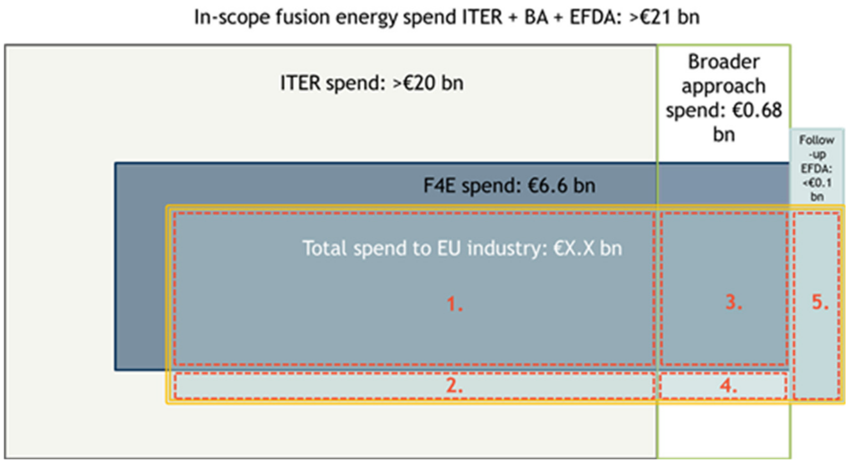
The dataset provides an inventory of payments related to contracts from F4E to EU industry [1 – in Figure 1-1 below], BA activities [3] and European Fusion Development Agreement (EFDA) [5] legacy contracts[11]. Financial flows from Japan (BA) to EU industry [4] are excluded from the dataset on the basis that these are negligible; information on contracting from other Domestic Agencies (DAs) towards EU industry [2] proved to be scarce. Although indications are that whilst there are some flows to EU industry from the other Domestic Agencies these are unlikely to be substantial and data was not

[11] These are fusion related contracts managed by DG RTD - EFDA prior to the creation of F4E in 2007, which were relevant to the ITER project and which ran later than 2007. The management of these contracts was therefore passed on to F4E. More analysis of the number and value of these contracts is provided in chapter 2.

accessible during the course of this work, therefore these were not pursued further. The current dataset captures more than 95% of relevant expenditure.

The database entries have been matched to economic sectors, which are consistent with the econometric model (E3ME) used in task 2.

Figure 1-1: Scope of ITER spending



Other important methodological aspects

- The economic matching has been done on the basis of expert judgement and making use of matching to the F4E Work Breakdown Structure (WBS), the F4E contractor assessment and technology code classification, and extracts from the Orbis database of Bureau van Dijk.
- The dataset provides financial flows (payments) per year per contract for main contractors, and in some cases for sub-contractors.
- An indication of expected future expenditures is also provided. This has been calculated on the basis of expected further EC financial commitments to ITER through to 2035, aligned with the latest EC communication[12].
- Further description of the approach used is provided in chapter 2 of this report.

1.2.2. Task 2: Impacts on the EU economy and competitiveness

Overview

In **task 2** we have used the data source from task 1 as the basis for a quantitative and qualitative analysis of the economic impact of funding to European industry from F4E contracting activities. We have created an analytical framework by identifying and categorising the main economic impacts and defining indicators that are used to measure these (see chapter 3). Task 2 included further data collection to bolster the economic impact analysis in the form of a beneficiary survey sent to more than 250 companies contracted by ITER. This survey received 82 responses, an approximate 30% response rate, and with a good spread across countries and sectors – for further detail see chapter 3. Case studies and stakeholder interviews were also carried out. Finally, an econometric analysis was carried out based on the outputs of task 1.

[12] https://ec.europa.eu/energy/sites/ener/files/documents/eu_contribution_to_a_reformed_iter_project_en.pdf

Specifics

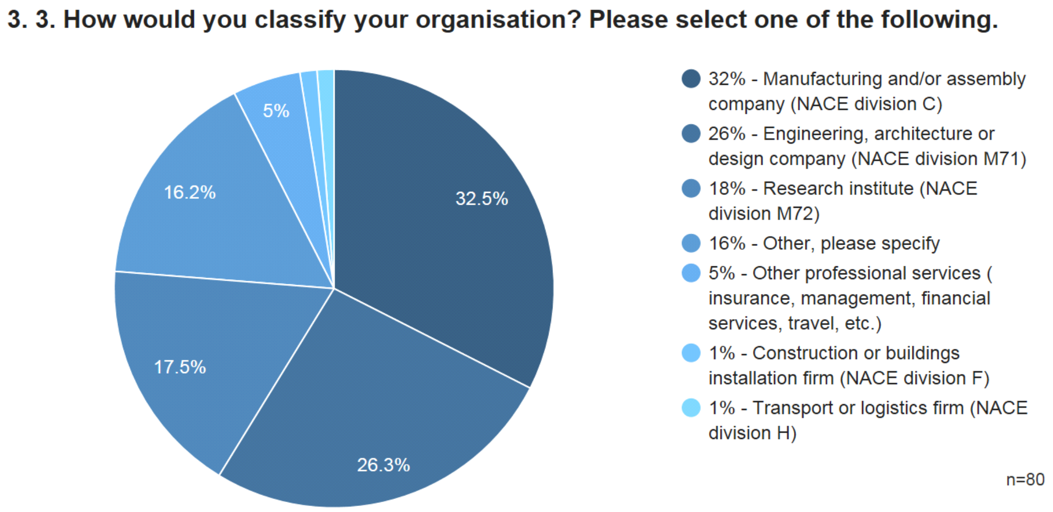
This task measures the impact of the funding to EU industry as a result of ITER through a quantitative and qualitative assessment of the main effects. The approach uses the E3ME model to quantitatively assess the impact of ITER spending on gross value added (GVA) and employment over the period 2008-2017 (see annex D for more details on the model and modelling approach). The study also uses the indicator framework, survey results and case studies to qualitatively assess other impacts and to illustrate these using case study examples.

The case studies help to give an illustration of the diversity of positive impacts of the ITER activities (as a Big Science project) in the EU. For example, they show that the current contracts and grants are not only related to high-tech development and innovation, but also have positive impacts on the low-skilled labour market. Likewise, the case studies also highlight the importance, and examples, of technology transfer to other sectors from ITER.

The survey

From the approximately 250 contacts that were invited to fill in the survey we obtained 83 responses (33%), out of which 67 (26%) responded fully to the survey, the other 16 provided input to only a limited number of the questions. This response rate compared well with the target rate (30%) and response rates achieved in similar studies. We incorporated all answers per question in the statistics presented below and in chapter 3, where we also indicate per question the number of responses to that particular survey question.

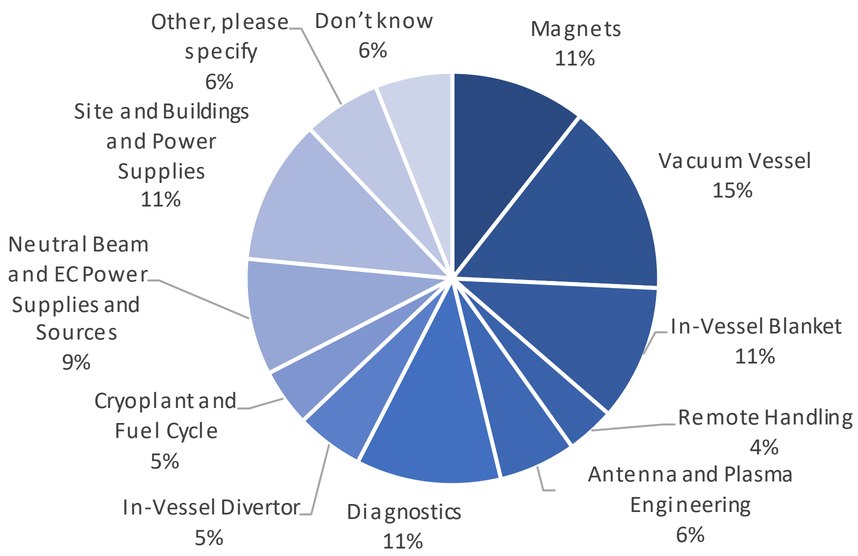
The respondents to the survey represent a range of different types of organisations and sectors. The following figure demonstrates the distribution of firms across the sectors, which shows the following distribution Manufacturing sectors (32%), Engineering, architecture and design (26%) and research institutes (18%). Of note is that only one firm claimed to represent the construction sector despite this being a major sector of activity. In our opinion, firms active in construction activities for ITER are likely to have self-classified as engineering, architecture or design firms (M71).



These companies report a total employment of around 537 000 people, of which around 3 800 are employed directly on fusion-related activities – this latter figure including one institute of 1 100 people working solely on fusion-related activities. The combined contract value that respondents filled in for the survey totals more than € 2.2 billion, even taking into account that these values are self-reported and may include some double counting the survey still managed to reach firms that have, or will, carry out a considerable portion (>50%) of the ITER work contracted to date.

More than half (55%) of the respondents that filled in the survey have been involved in the implementation of more than one ITER contract. In these cases, the answers the respondents gave usually refer to the portfolio of ITER contracts implemented. For the other 45% their answers are based on their experience with that particular contract. For the contracts themselves there is a broad distribution across the different work packages, meaning that the responses are based on a good variety of activities in the project.

Figure 1-2: Distribution of contracts across the main ITER project Work Streams, n=132.



1.2.3. Task 3: Cross-cutting analysis of ITER contributions

Overview

In **task 3,** we focused our efforts on analysis and reporting also on the thematic factsheet deliverables. The analysis and reporting involved several analytical sub-tasks building on the work carried out in task 2, including: an aggregate economic analysis of the results; followed by a series of analyses of the aggregated impact of ITER compared to other energy technologies and Big Science projects; and also comparing with other EU policies and strategies.

Specifics

The objective of this task is to assess ITER impacts by making a cross-cutting assessment of the contribution of ITER to EU energy, innovation and research policies. It puts the findings from tasks 1 and 2 into context and provides additional interpretation and analysis. The analysis for this task is based on a mix of desk research, econometric modelling results and stakeholder interviews.

2. Analysis of ITER contract payments

Key findings

- An estimated €20.6 billion euros will be spent in Europe as a result of the ITER project in the period 2008-2035, including more than €2 billion as a 'multiplier' from the ITER Organisation.
- Around €2.25 billion has already been spent on in-kind contributions by F4E.
- Spending will increase towards first plasma before peaking at around €1.2 billion per year in 2022.
- Over time the proportions of spending on construction will decrease and more money is expected to flow into high value manufacturing and services, with the former representing more than 50% of the total estimated spend between 2018-2035.
- As host country France makes outsize financial contributions, but a large part of the spending is also expected to take place in France.
- The cash sent to the ITER Organisation by F4E is expected to deliver economic multipliers in return.

2.1. The approach and payments

The dataset file has been supplied alongside this report as an Excel file. In this section we present an analysis of the contract and payment data provided by F4E to supplement the impact analysis and provide insight into the data that was used as inputs in the econometric modelling. The analysis provides insight into the spread and distribution of activity by geography, ITER Work Package and economic sector.

A point on terminology - contracts and payment lines

F4E procures services for ITER by contracting various consortia or organisations.

Contract: each contract is allocated a reference number, typically in the format F4E-XXX-NNN, where the XXX represents the type of contract (e.g. OPE=Operational, GRT=Grant) and the NNN is an identifying number. This forms a unique identifier for the contract.

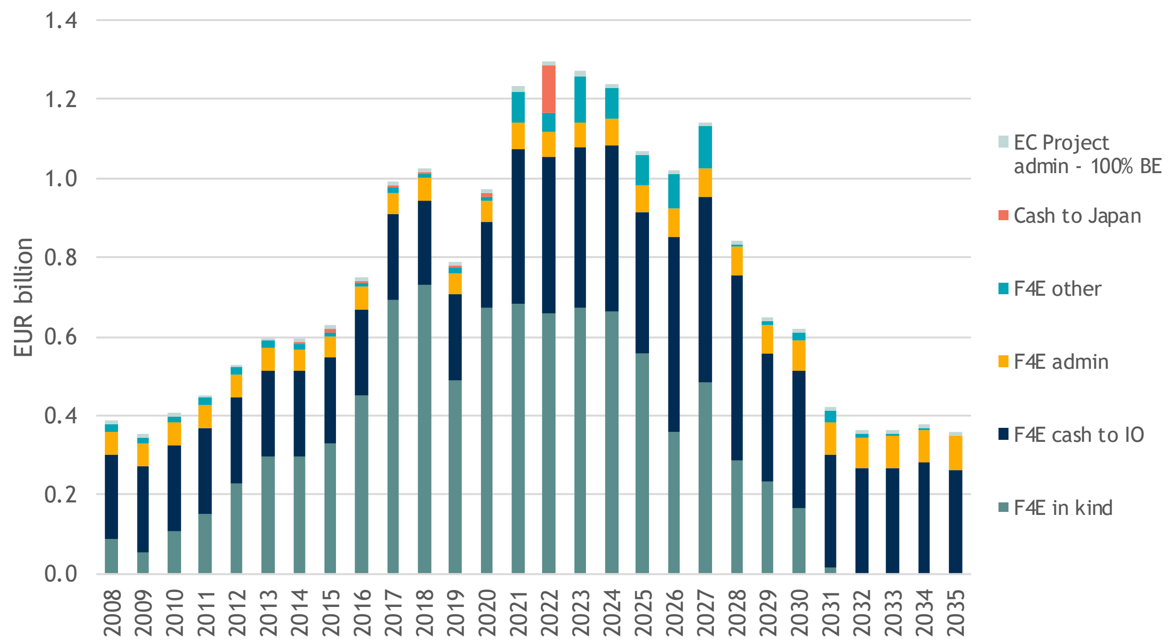
Payment line: the payment database shared by F4E which forms the basis of the dataset includes payment lines, typically one per contractor per contract. As some contracts have multiple contractors (including different legal entities of the same main contractor at holding level, e.g. company ABC Ltd [UK] and company ABC Gmbh [DE]), or payments to the same company that are split into phases or lots, there can be, and often are, multiple payment lines per contract.

In addition to payment lines in the main dataset received from F4E we have also added further lines based on sub-contractor information received in an additional dataset received from F4E. Using these it has been possible to split the existing main contractor line over the multiple sub-contractors in proportion to their share of the overall work.

As noted in section 1.2 the scope of the work covers not only the in-kind payments that have been made to date, but also other payments by F4E to date and the expected payments in future. These have been modelled and used as inputs for the econometric impact analysis. This section provides an overview of these other payments and also their geographic, work package and economic sector spread. The key source of these values was the Staff Working Document accompanying the EC Communication on ITER (SWD [2017] 232 Final) which provides detailed breakdowns. Following consultation with the EC and F4E certain adjustments to these values have been applied as described below.

Over the full period (2008-2035) around €20.6 billion Euros is expected to be spent in Europe by F4E and the ITER Organisation. This is shown annually in Figure 2-1 which demonstrates how spending is expected to increase and peak in the early 2020s prior to first plasma and then start to decline as the device is completed around 2030. The biggest categories of spending are the F4E in-kind contributions and the F4E cash to IO.

Figure 2-1: Summary of estimated annual spending on ITER in EU28



Source: Trinomics - see accompanying dataset.

The full scope of the different payment lines per year is provided in Table 2-1 below.

The following bullet points describe each of these contributions and briefly explain how each was modelled:

- **F4E cash to IO:** This was split by four different sub-categories, construction, operations, upgrades and operational spares and decommissioning/deactivations. An assumption was made, based on existing experience that because a larger share of IO activities take place in France than the EU share of the ITER project, a multiplier could be applied to the values in the SWD. The multiplier was based on advice from F4E and actual data for 2016, which was analysed and interpreted to provide conservative estimates of multipliers. The application of these multipliers means that the totals in the table do not exactly match those in the SWD. The following assumptions were also applied to each sub-category:

- Construction – this was allocated to economic sectors in the same proportion as the in-kind contributions (less activities in the Buildings infrastructure and power supplies WBS code) for the same year. Payments were allocated 80% to France and 20% to the rest of the EU28. A multiplier of 1.3 was used for these payments;
- Operations – these were allocated 80% to France, 20% to the rest of the EU28. The payments allocated to France were split equally between the economic sectors for power supply (equally again between both D351 Electricity and D352-353 Gas, steam and air conditioning) and scientific research (M72), this representing both the (fuel) consumables to operate the device and staff and other costs in its operation and associated research. The 20% to the EU28 was also allocated to scientific research (M72). A multiplier of 1.6 was used for this spending;
- Upgrades and operational spares – this was allocated in the same proportion as the in-kind contributions (less activities in the Buildings infrastructure and power supplies WBS code) for the same year. Payments were allocated 80% to France and 20% to the rest of the EU28. A multiplier of 1.6 was used for these payments;
- Decommissioning/Deactivation – this was allocated 100% to France and to the Waste remediation economic sector (E38). A multiplier of 1.6 was used for these payments.

- **F4E in-kind:** This line represents the main contracting undertaken by F4E and the most interesting spending on the construction, manufacturing and technical services required for ITER. It represents around half of the total F4E spend. Within the dataset the historic payments to date were allocated on the basis of the work package, location of the firm and expert judgement on the particular task being carried out. Future payments were allocated using F4E planning documents (namely the draft annual and multiannual programme 2018-2022) we have analysed the ITER Work Packages that are planned to be implemented per year (per ITER credits[13]). The allocation spreads credits across 66 different work items. For years up to 2022 the specific annual credits are planned. From 2023 onwards only a total up to 2035 was available. Therefore, we spread credits proportionally across the years taking into account the planned close out dates per individual work package item. Finally, the credits were converted to euros, by assuming that the total of the credits was equal to the estimated €7.5 billion additional spending yet to occur through to 2035. The credits were allocated geographically in two ways:
  1. 50% on the basis of the known payments in the period up to 2017, e.g. if Austria received 29% of the payments for WP code 01.17.02 Divertor Rails in the previous period it was assumed to receive a similar proportion in future;
  2. 50% in proportion to the share of EU GVA of the Member State for the specific economic sector to which a work package is matched, to account for the fact that a Member State may not have received a payment in the past but may in future, and most likely in proportion to their share of GVA in the related economic sector.

A few additional reallocations were made to better reflect the likely reality of payments, including:

- A proportion (11%) of the euros forecast to be spent in manufacturing sectors were reallocated to sector M71: Architecture, design and engineering, to reflect the fact that

[13] ITER credits or units of account (IUAs) are the accounting mechanism used within the ITER project as a whole to credit the delivery of a particular Work Package by one of the ITER consortium members.

whilst manufacturing may be the leading activity there are also significant engineering, design and other support activities. The proportion used was based on the 2008-2017 actual figures;

- 5% of the total construction budget was reallocated 3 other sectors, J62-63 Computer programming, M72 Research and Development, and N80-82 Security and Administration, to reflect the fact that these activities despite being part of the ITER work did not have specific funding from the conversion from work package credits. Within the 5% reallocation R&D was given a relatively higher share over time to reflect the growing ability for research to be carried out using the ITER machine in the lead up to, and following, planned first plasma in 2026.

- **F4E Admin:** This line represents the work carried out by F4E in Barcelona and at the ITER site. It is allocated 80% to Spain and 20% to France. In both cases the spending is allocated 100% to the economic sector for Public Administration (O84).

- **F4E other:** This line represents other work related to ITER contracted by F4E. This was allocated to economic sectors in the same proportion as the in-kind contributions (less activities in the Buildings infrastructure and power supplies WBS code) for the same year. Payments were allocated 100% to the EU28 split in the same geographic proportions as the in-kind payments.

- **Cash to Japan:** This line represents money paid directly to Japan for the implementation of the Broader Approach. This was allocated 100% to Japan and in proportion to the Broader Approach spending per WBS code as included in the historic dataset of in-kind payments.

- **EC project admin:** This line represents the work undertaken by the European Commission in Brussels to manage the ITER project from a policy perspective. These payments were allocated 100% to Belgium and the main contracting undertaken by F4E and the economic sector for Public Administration (O84).

Note that the Revenue to RF payment line included in the SWD was excluded from the analysis on the advice of F4E and the EC.

Clearly this approach includes a number of assumptions, as described above, which should be kept in mind when reading the interpretation and analysis of the results presented in the following sections.

Table 2-1: Summary of model inputs per main category

Current Euros (billions)	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	Sub-total 2008-2017
F4E cash to IO	0.130	0.051	0.101	0.124	0.104	0.094	0.217	0.217	0.217	0.217	**1.471**
Of which:											
Construction	*0.130*	*0.051*	*0.101*	*0.124*	*0.104*	*0.094*	*0.217*	*0.217*	*0.217*	*0.217*	***1.471***
Operations	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*	***0.000***
Upgrades& operational spares	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*	***0.000***
Decommissioning/deactivation	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*	***0.000***
F4E in kind	0.079	0.049	0.099	0.143	0.219	0.287	0.289	0.323	0.448	0.776	**2.711**
F4E admin	0.015	0.024	0.029	0.036	0.039	0.040	0.055	0.055	0.055	0.055	**0.402**
F4E other	0.004	0.017	0.009	0.009	0.003	0.011	0.011	0.011	0.011	0.011	**0.099**
Cash to Japan	0.006	0.018	0.009	0.010	0.204	0.080	0.006	0.006	0.006	0.006	**0.352**
EC project admin	0.008	0.008	0.008	0.008	0.008	0.008	0.010	0.010	0.010	0.010	**0.090**
Total	**0.242**	**0.167**	**0.255**	**0.330**	**0.577**	**0.520**	**0.589**	**0.623**	**0.748**	**1.075**	**5.125**

Current Euros (billions)	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	Sub-total 2018-2035	Total 2008-2035
F4E cash to IO	0.651	0.217	0.217	0.395	0.397	0.402	0.421	0.356	0.496	0.471	0.466	0.322	0.348	0.289	0.266	0.266	0.281	0.263	**6.520**	**7.991**
Of which:																				
Construction	*0.434*	*0.217*	*0.217*	*0.395*	*0.397*	*0.402*	*0.421*	*0.254*	*0.238*	*0.242*	*0.213*	*0.077*	*0.122*	*0.052*	*0.014*	*0.014*	*0.051*	*0.012*	***3.771***	***5.241***
Operations	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*	*0.102*	*0.166*	*0.138*	*0.162*	*0.154*	*0.134*	*0.146*	*0.160*	*0.160*	*0.139*	*0.160*	***1.621***	***1.621***
Upgrades& operational spares	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*	*0.058*	*0.058*	*0.058*	*0.058*	*0.058*	*0.058*	*0.058*	*0.058*	*0.058*	*0.058*	***0.576***	***0.576***
Decommissioning/deactivation	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*	*0.034*	*0.034*	*0.034*	*0.034*	*0.034*	*0.034*	*0.034*	*0.034*	*0.034*	*0.034*	***0.336***	***0.336***
F4E in kind	0.885	0.594	0.816	0.681	0.657	0.675	0.663	0.557	0.356	0.482	0.287	0.233	0.167	0.013	0.000	0.000	0.000	0.000	**7.067**	***9.778***
F4E admin	0.110	0.055	0.055	0.065	0.066	0.067	0.069	0.070	0.071	0.073	0.074	0.076	0.077	0.079	0.080	0.082	0.084	0.085	**1.337**	***1.740***
F4E other	0.023	0.011	0.011	0.080	0.044	0.116	0.075	0.077	0.089	0.104	0.005	0.007	0.016	0.032	0.006	0.004	0.002	0.000	**0.703**	***0.801***
Cash to Japan	0.013	0.006	0.006	0.000	0.122	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	**0.147**	***0.499***
EC project admin	0.020	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	**0.190**	***0.280***
Total	**1.701**	**0.894**	**1.116**	**1.231**	**1.296**	**1.270**	**1.238**	**1.070**	**1.022**	**1.140**	**0.842**	**0.648**	**0.618**	**0.423**	**0.362**	**0.362**	**0.377**	**0.358**	**15.965**	***21.090***

Sources: Trinomics – see accompanying dataset, EC COM (2017) 319 Final, EC SWD (2017) 232 Final.

Note: The payment line for in-kind payments in 2017 includes both those paid to mid-2017 as recorded in the dataset, plus an estimate of those to be paid in the remainder of the year. The sub-total 2008-2017 is equivalent to the historic payments analysed in 2.1. The F4E cash to IO amount includes the multiplier effect as described previously, this inflates the total by €2.106 billion over the full period.

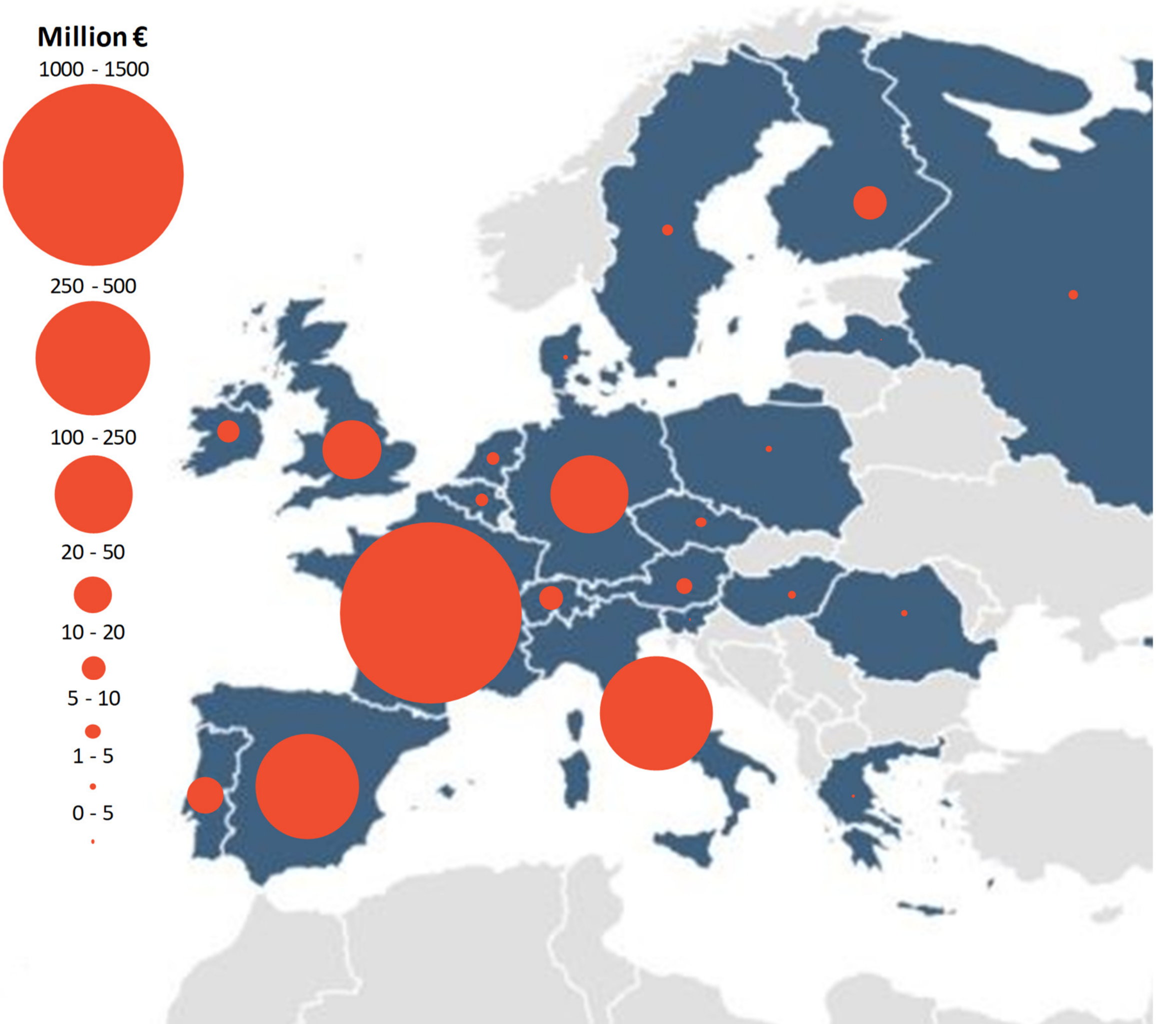
2.2. Analysis of payments to mid-2017 (in-kind contributions only)

Based on data from F4E in kind payments totalled €2.245 billion in the period 2008-mid-2017 (€2.309 billion in 2017 values if deflators are applied). The following section analyses where this money was spent.

2.2.1. Analysis of geographical distribution

At country-level, contracting activity clusters in 11 countries (those that received more than €10 million over the period), this includes both the US and China. France, as the host-country of the ITER device, has to date received the highest share of the contract value that has been paid out (€1.01 billion). It should be noted that France also provides a larger contribution to F4E to balance this benefit, e.g. almost €1.4 billion of the €7.7 billion in the 2007-2020 MFF periods. Figure 2-2 presents the total amount of payments within the payment dataset from F4E to each of the Euratom member states and other ITER collaborators.

Figure 2-2 Geographical distribution of F4E payments



Source: Trinomics - see accompanying dataset.

As can be seen in Figure 2-2, other important European contractors for F4E include those from Italy (EUR 401M), Spain (EUR 335M), Germany (EUR 188M), and the United Kingdom (EUR 107M), the other 4 of the EU 'big 5'. A complete overview of the amounts paid and the number of payment lines per country is given in the summary Table 2-2.

Important note: the table refers to individual payment lines, not contracts, of which there are fewer, please refer back to the box text at the start of this section. It also does not include all sub-contract activity that is taking place. As a result, there may well be activity in countries that are presented as having not received any payments, but it has not been possible to capture these in the available datasets.

Table 2-2 Summary table of geographical distribution of F4E payments

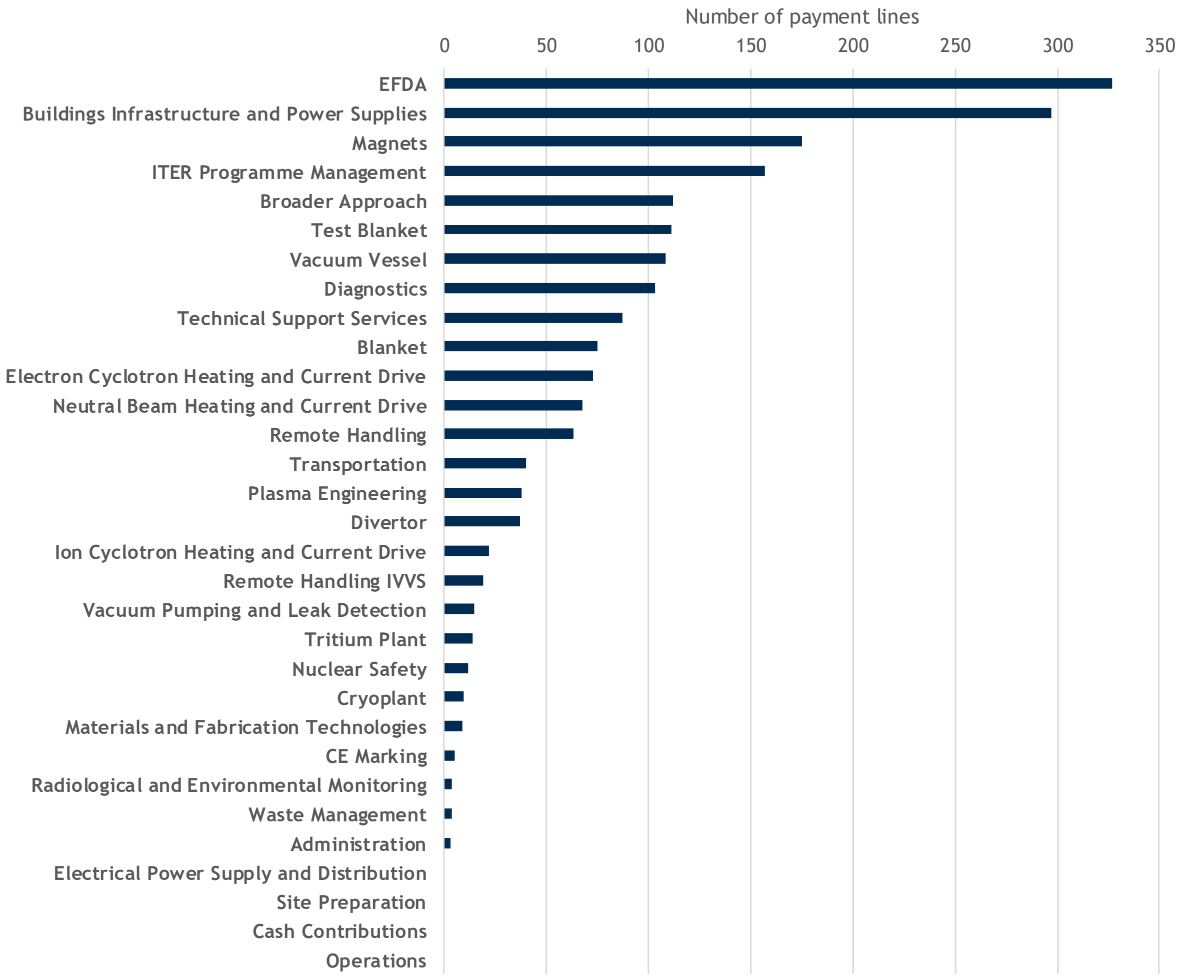
Country code	Country	Amount Paid	Number of payment lines	Number of payment lines as % of total	Amount Paid as % of total
AT	Austria	6 952 425	14	0.70%	0.31%
BE	Belgium	4 771 155	28	1.41%	0.21%
BG	Bulgaria	0	0	0.00%	0.00%
CY	Cyprus	0	0	0.00%	0.00%
CZ	Czech Republic	3 550 554	14	0.70%	0.16%
DE	Germany	187 502 981	236	11.87%	8.35%
DK	Denmark	745 736	2	0.10%	0.03%
EE	Estonia	0	0	0.00%	0.00%
EL	Greece	191 136	3	0.15%	0.01%
ES	Spain	335 023 482	389	19.57%	14.92%
FI	Finland	35 620 224	49	2.46%	1.59%
FR	France	1 011 815 623	514	25.86%	45.07%
HR	Croatia	0	0	0.00%	0.00%
HU	Hungary	1 780 813	15	0.75%	0.08%
IE	Ireland	15 366 115	3	0.15%	0.68%
IT	Italy	401 348 925	294	14.79%	17.88%
LT	Lithuania	0	0	0.00%	0.00%
LU	Luxembourg	0	0	0.00%	0.00%
LV	Latvia	83 417	5	0.25%	0.00%
MT	Malta	0	0	0.00%	0.00%
NL	Netherlands	4 489 988	27	1.36%	0.20%
PL	Poland	1 212 597	9	0.45%	0.05%
PT	Portugal	42 502 347	52	2.62%	1.89%
RO	Romania	1 256 392	11	0.55%	0.06%
SE	Sweden	3 172 531	28	1.41%	0.14%
SI	Slovenia	189 793	7	0.35%	0.01%
SK	Slovakia	0	0	0.00%	0.00%
UK	United Kingdom	107 190 427	202	10.16%	4.77%
	EU28 Sub-Total	**2 164 766 660**	**1902**	95.67%	96.42%
CH	Switzerland*	16 708 520	54	2.72%	0.74%
US	United States	40 994 393	7	0.35%	1.83%
JP	Japan	8 481 499	17	0.86%	0.38%
CN	China	11 387 202	3	0.15%	0.51%
RU	Russia	2 707 700	4	0.20%	0.12%
IN	India	0	0	0.00%	0.00%
KO	Korea	0	0	0.00%	0.00%
CA	Canada	38 667	1	0.05%	0.00%
IO	ITER IO	0	0	0.00%	0.00%
	Sub-Total	**80 317 981**	**86**	4.33%	3.58%
	Total	**2 245 084 641**	**1988**		

Source: Trinomics - see accompanying dataset.
*=Note that Switzerland is an associated state to Euratom and therefore a contributor to F4E, but is not directly within the scope of EU28 countries considered in this work.

2.2.2. Analysis of Work Package distribution

The road to First Plasma in 2025 currently shapes the contracting activity of F4E. When divided into the specific F4E Work Package codes, the data reveals that over 75% of payments have – until now – gone to construction activities (mainly on-site in Cadarache) and the development and construction of the superconducting magnets. The distribution of payment lines between Work Package codes is a lot less skewed, as can be seen in Figure 2-3. This shows that the legacy EFDA payments made by F4E form the largest number of payment lines in the dataset, although these only represent a relatively small share of the total payments (see Table 2-3), as noted above the highest number of payment lines are related to the buildings infrastructure and power supplies and the magnets work packages.

Figure 2-3 Work Package distribution of number of payment lines



Source: Trinomics - see accompanying dataset.
Note: EFDA contracts do not carry a Work Package code. They are included here for visualisation but the nature of the payment lines (contracts) could be associated to any of the other work package areas.

The figure also shows that the engineering, construction, and installation processes of other crucial parts of the ITER machine have not been neglected, despite the financial intensity of constructing the buildings and magnets. Other parts crucial to First Plasma, like the blankets and vacuum vessels, have also seen significant payment activity. A summary of amounts paid and number of payment lines per Work Package code is presented in Table 2-3.

Table 2-3 Summary table of Work Package distribution of F4E payments

Work Package Codes	Description	Amount Paid	Ratio of total value	Number of payment line total	Ratio of total payment lines number	Average payment line value
11	Magnets	560 201 233	25%	175	9%	3 201 150
15	Vacuum Vessel	116 541 390	5%	108	5%	1 079 087
16	Blanket	27 580 737	1%	75	4%	367 743
17	Divertor	23 089 397	1%	37	2%	624 038
23	Remote Handling	21 212 891	1%	63	3%	336 713
31	Vacuum Pumping and Leak Detection	4 123 229	0%	15	1%	274 882
32	Tritium Plant	5 662 367	0%	14	1%	404 455
34	Cryoplant	67 132 721	3%	10	1%	6 713 272
41	Electrical Power Supply and Distribution	0	0%	0	0%	0
51	Ion Cyclotron Heating and Current Drive	5 103 818	0%	22	1%	231 992
52	Electron Cyclotron Heating and Current Drive	19 620 033	1%	73	4%	268 768
53	Neutral Beam Heating and Current Drive	62 174 139	3%	68	3%	914 326
55	Diagnostics	22 443 424	1%	103	5%	217 897
56	Test Blanket	26 182 076	1%	111	6%	235 875
57	Remote Handling IVVS	2 327 563	0%	19	1%	122 503
61	Site Preparation	0	0%	0	0%	0
62	Buildings Infrastructure and Power Supplies	1 162 488 116	52%	297	15%	3 914 101
64	Radiological and Environmental Monitoring	757 073	0%	4	0%	189 268
66	Waste Management	283 534	0%	4	0%	70 883
CC	Cash Contributions	0	0%	0	0%	0
CE	CE Marking	476 511	0%	5	0%	95 302
ES	Technical Support Services	6 187 348	0%	87	4%	71 119
MF	Materials and Fabrication Technologies	463 552	0%	9	0%	51 506
NS	Nuclear Safety	1 056 126	0%	12	1%	88 010
PE	Plasma Engineering	2 795 719	0%	38	2%	73 572
PM	ITER Programme Management	12 083 979	1%	157	8%	76 968
TR	Transportation	13 106 056	1%	40	2%	327 651
AD	Administration	111 729	0%	3	0%	37 243
BA	Broader Approach	19 867 968	1%	112	6%	177 393
OP	Operations	0	0%	0	0%	0
EF	EFDA	62 011 913	3%	327	16%	189 639
	Total	**2 245 084 641**		**1988**		

Source: Trinomics – see accompanying dataset.

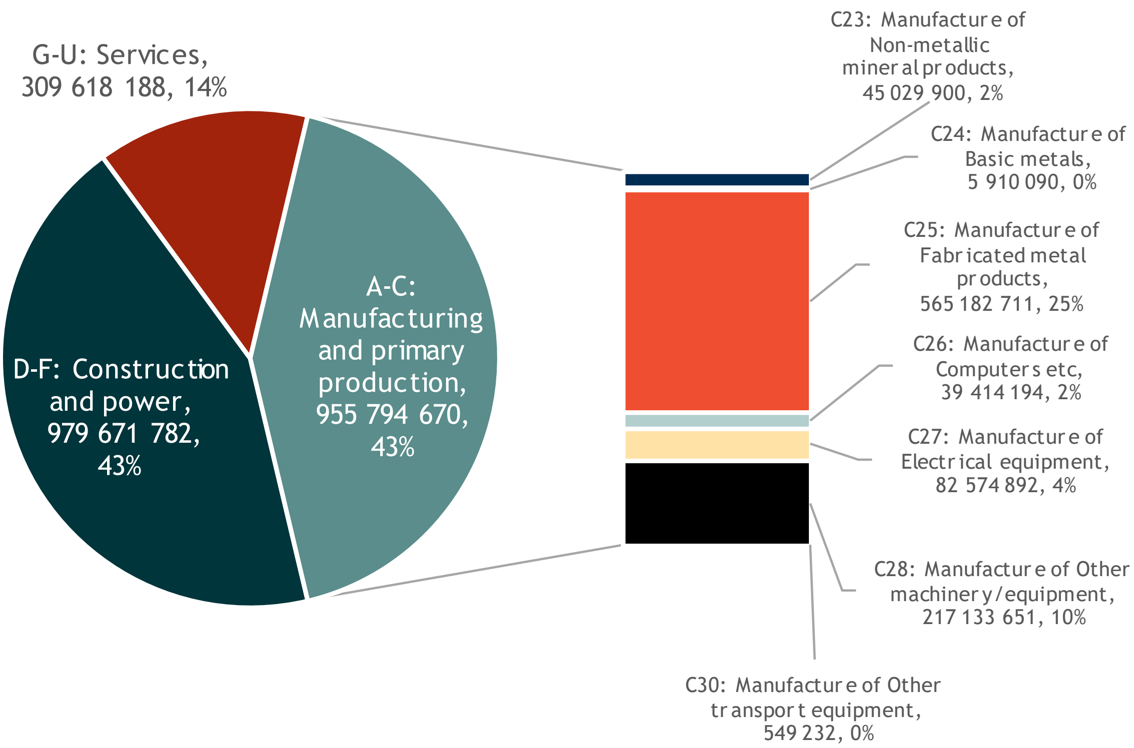
2.2.3. Analysis of economic sector distribution

An important deliverable of the dataset is a matching exercise of the payment lines with their respective NACE sector[14]. This enables the analysis of the economic impacts of the F4E contracting activities via operationalisation of the E3ME model in subsequent tasks of the project. It also provides an overview of the sectors that are involved in ITER-related contracts inside the European Union. Beyond giving an indication of the specific ITER-part the payment line is targeting (as do the Work

[14] The Statistical Classification of Economic Activities in the European Community, commonly referred to as NACE (for the French term *"nomenclature statistique des activités économiques dans la Communauté européenne"*), is the industry standard classification system used in the European Union.

Package codes), the NACE codes offer a description of the nature of the activity behind the payment. Figure 2-4 presents the three main economic sectors relevant for this work (Construction, Manufacturing and Services), and also provides a split of the five most important manufacturing sectors.

Figure 2-4 NACE Code distribution of F4E payments [Sector, EUR, % of total]



Source: Trinomics - see accompanying dataset.

As with the Work Package analysis, construction (F41-43) and manufacturing take the joint largest share of payments (43% each). Services constitute the remainder (14%), of which the majority are in Architecture & engineering (M71) activities (10%). Within manufacturing the payments are focused on a handful of sectors, and particularly the manufacture of fabricated metal products and other machinery and equipment (C25 & C28) sectors, which account for 35% of payments. The number of payment lines is high for manufacturing and services in comparison to construction.

Table 2-4 Summary table of NACE code distribution of F4E payments

NACE Description	Amount Paid	Ratio of total value	Number of payment lines total
D-F Construction (and power and utilities)	979 671 782	44%	281
G-U Services	309 618 188	14%	809
A-C Manufacturing (and primary production)	955 794 670	43%	898
Of which:			
C25 Fabricated metal prods	*565 182 711*	*25%*	*176*
C28 Other machinery/equipment	*217 133 651*	*10%*	*195*
C27 Electrical equipment	*82 574 892*	*4%*	*140*
C23 Non-metallic mineral prods	*45 029 900*	*2%*	*177*
C26 Computers etc	*39 414 194*	*2%*	*197*
All other manufacturing	*6 459 322*	*0%*	*13*
Total	**2 245 084 641**		**1988**

Source: Trinomics - see accompanying dataset.

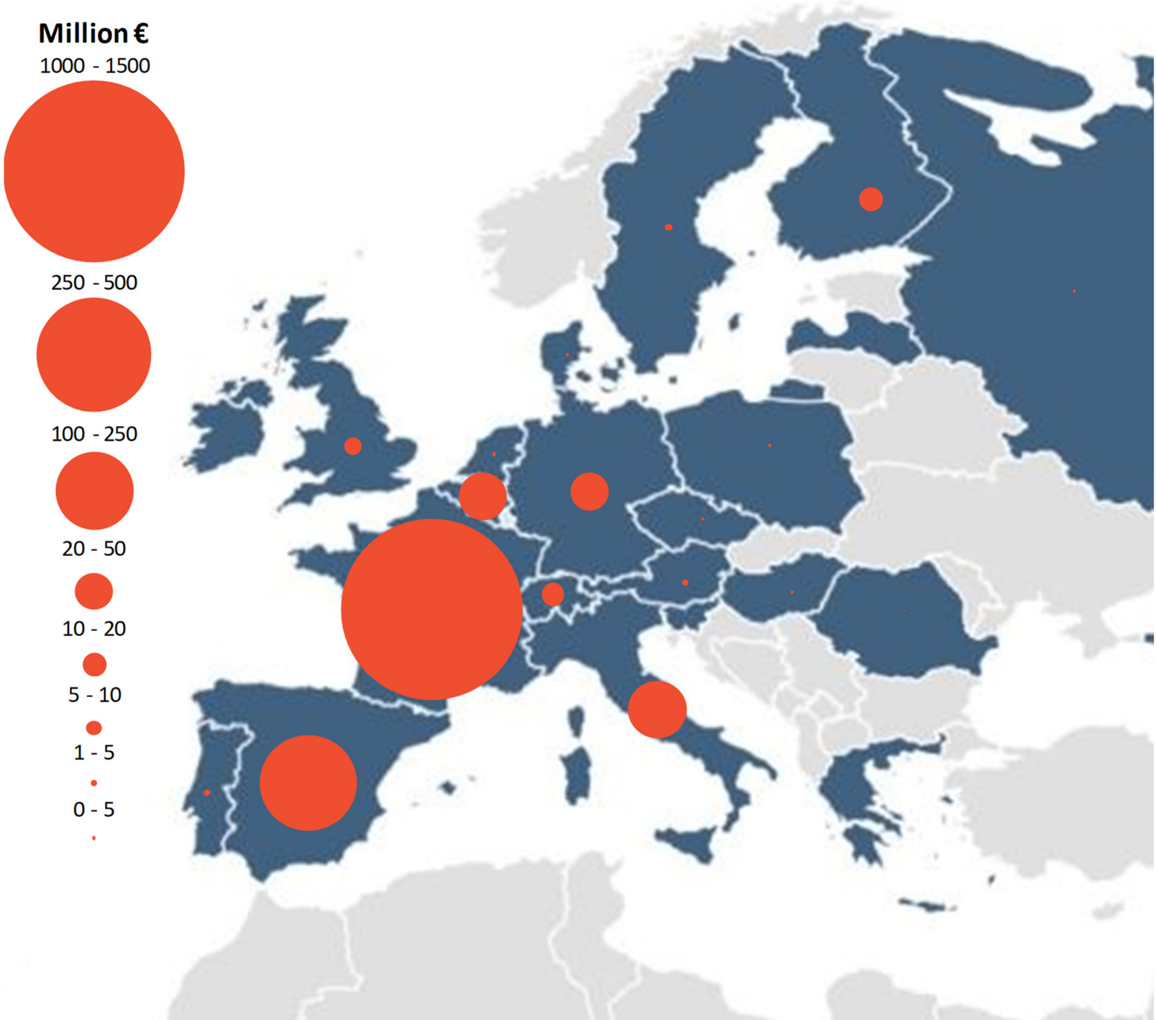
2.3. Analysis of other payments 2008-2017

The ex-post econometric modelling analysis, the results of which are presented in chapter 3, consider not only the in-kind payments analysed in the previous section (from 2008-mid 2017) but also the other payment types in this same period, and the in-kind payments for the rest of 2017. This encompasses a further €2.88 billion of spending.

2.3.1. Analysis of geographical distribution

Looking at the geographic spread of payments the largest share of payments again go to France (€1 220 million) as the assumed major recipient of the cash from IO spending. Other major beneficiaries include Spain (€345 million) and Belgium (€86 million), representing the cash spent in these countries for F4E and EC admin respectively. The remainder represents the spending on F4E other, split across the EU28.

Figure 2-5: Geographic distribution of F4E payments non in-kind contributions 2008-mid 2017

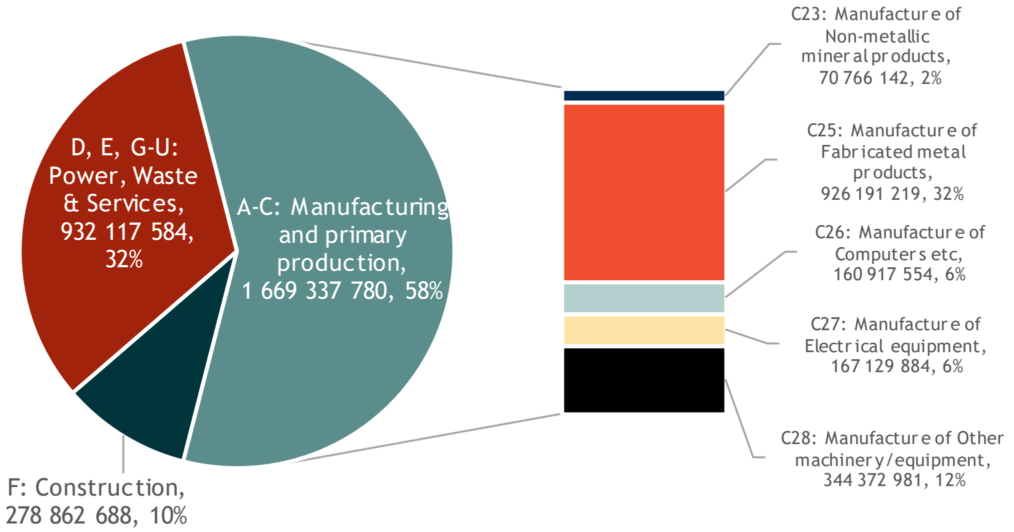


Source: Trinomics - see accompanying dataset.

2.3.2. Analysis of economic sector distribution

The distribution of the spending across economic sectors is also of interest. This shows that in the future scenario, once the spending is converted to economic sector impact and the reallocations have been made, that the payments are spread across 12 different economic sectors. In contrast to the results presented in section 2.2.3 the construction sector is absent due to the assumptions that the activities in the other areas of spending are not directly in the construction sector. As a result around 58% of the spending is assumed to have occurred in the manufacturing sectors, particularly in the manufacture of fabricated metal products. Of the remaining spending, 32% is estimated to have occurred in the power, waste and services sectors, whilst 10% will occur in construction.

Figure 2-6: Distribution of non in-kind payments across economic sectors, 2008-mid-2017, euros.



Source: Trinomics – see accompanying dataset.

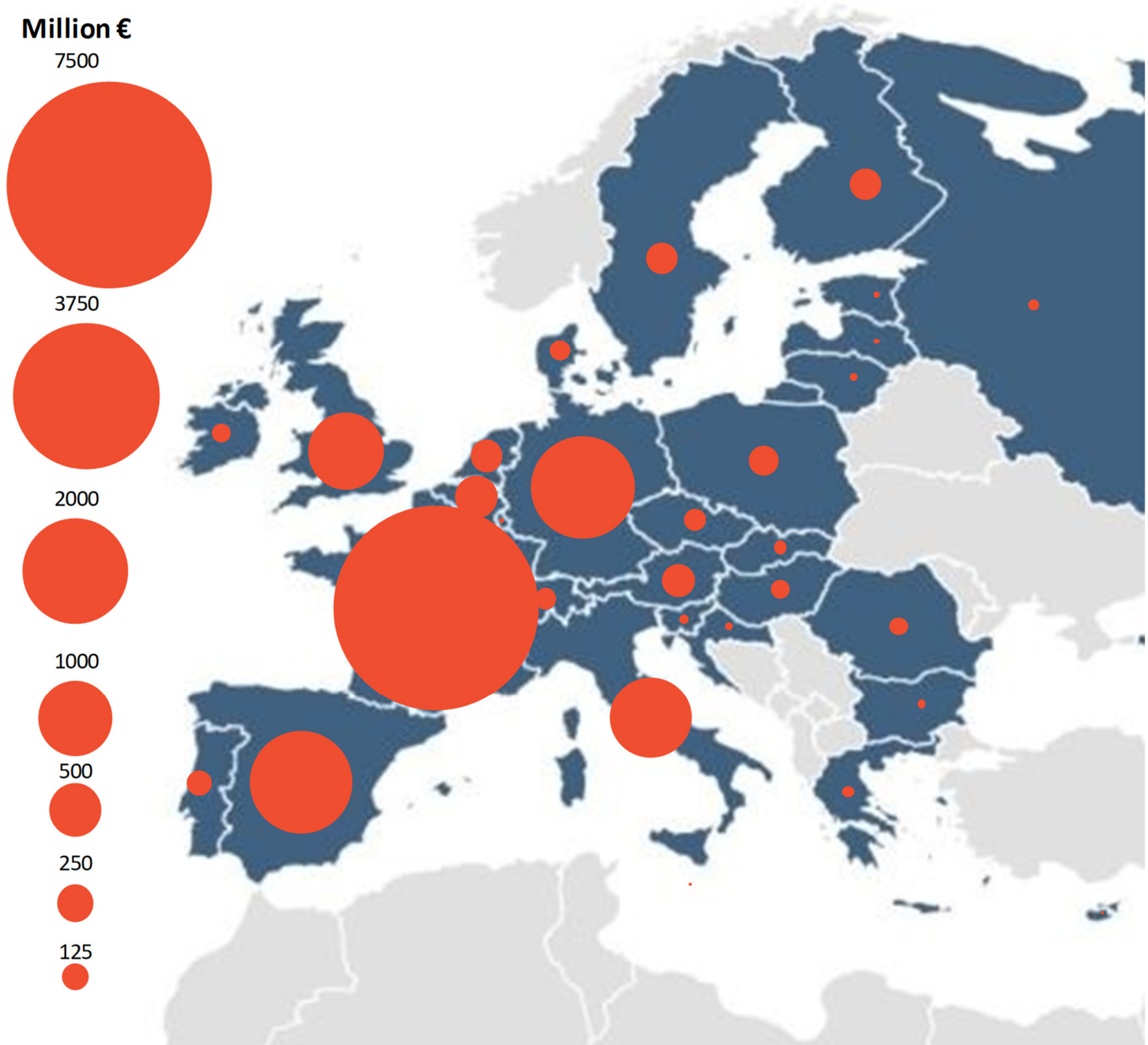
2.4. Analysis of projected future payments

The forward looking econometric analysis (modelling results presented in chapter 4) also considers all payment types, not only the in-kind contributions. This section provides a short overview of all future payments up to 2035 and their categorisation as input for the econometric analysis. This encompasses a further €13.9 billion of spending, plus an additional multiplier effect of around €2.0 billion, for a total of around €15.9 billion.

2.4.1. Analysis of geographical distribution

Looking at the geographic spread of payments as anticipated in this future scenario the largest share of payments go to the five biggest EU Member States. France is estimated to be the largest beneficiary in future as host, receiving almost €7.5 billion over the next 18 years. Germany (€1.87 billion), Italy (€1.16 billion), the United Kingdom (€1.02 billion) and Spain (€1.86 billion) are the other largest recipients.

Figure 2-7: Geographic distribution of F4E payments in the future scenario 2017-2035

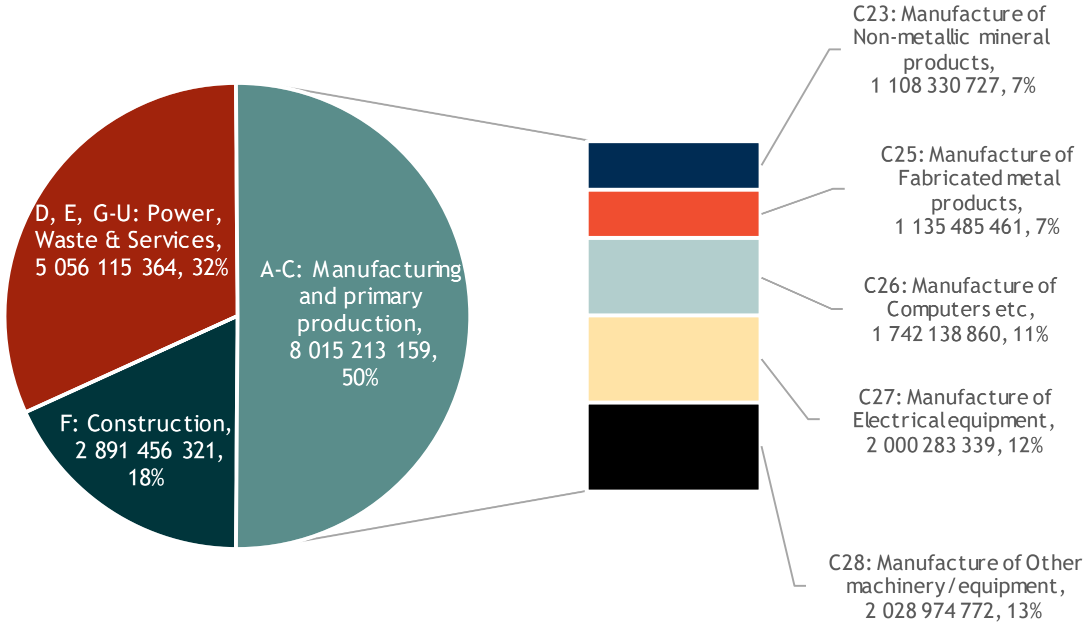


Source: Trinomics - see accompanying dataset.

2.4.2. Analysis of economic sector distribution

The distribution of the spending across economic sectors is also of interest. This shows that in the future scenario, once the spending per work package is converted to economic sector impact and the reallocations have been made, that the payments are spread across a range of sectors. In total the forecast we have constructed allocates payments across 13 different economic sectors. At the broad level of construction, manufacturing and services we find around half of the total spending goes to manufacturing, and around 32% to power, waste and services. This contrasts with the historical outcomes where the share of construction at 43% was much higher than in this forecast (18%). This represents the progression of the project over time as the efforts move to focus more on manufacture, assembly and operation.

Figure 2-8: Distribution of future scenario payments across economic sectors, 2017-2035, euros.



Source: Trinomics – see accompanying dataset.

3. Impact analysis

Key findings
• Spending on ITER by F4E is having significant positive economic impacts compared to no spending, with 34 000 job years created to date, including 7 400 in 2017 alone; and almost €4.8 billion in gross value added (GVA) to date, with more than €1.1 billion in GVA estimated in 2017. • Benefits increase further from spin-offs, indicative modelling results suggest that this further increased the gross impacts by around 10-15%, but more importantly in terms of net impacts adding a further €78 million in GVA (+59%) and 1 400 job years (+24%) between 2008-2017 • Around 1/3 of surveyed firms have developed new cutting edge technologies and ¼ report that working on ITER had opened up new business opportunities or markets. These are indicative of the significant innovation, market and growth benefits for EU firms working on ITER. • Most firms have had develop new knowledge and skills as a result of working on ITER, around 25% acquiring substantially new knowledge and skills, particularly in high-tech engineering. These are important gains in innovation for EU firms, and indeed companies find that working on ITER provides a significant reputation boost as a leading high-tech company and that this will support future financial growth. • Firms see working on ITER as part of their core business, but also as an opportunity to develop longer term benefits and spin-offs.

This chapter describes the main economic effects emerging from the implementation of F4E contracts. These concern short-term effects, directly related to the implementation of the contract, and also medium to longer-term effects, as a result of spin-offs that materialise as a result of contract implementation, both inside fusion and in particular also outside fusion.

The analysis is based on desk review, the stakeholder survey (see section 1.3.2 for more information), case studies and the application of the E3ME model to establish the impacts of the ITER project activities in the EU on jobs and gross value added (GVA) over the period 2008-2017.

3.1. Summary: dashboard impact indicators

Table 3-1 presents a summary overview of the information obtained to measure the main economic effects emerging from the implementation of F4E contracts, as further presented and discussed in this chapter, and including the following observations:

- Firstly, the spending on ITER by F4E is having significant positive economic impacts compared to no spending, with 34 000 job years created to date, including 7 400 in 2017 alone; and almost €4.8 billion in GVA to date, with more than €1.1 billion in GVA estimated in 2017;
- Secondly, indicative modelling analysis of the benefits of spin-offs suggests that these would increase gross benefits around 10-20% in each case, but most importantly they deliver significant net benefits, adding a further €78 million in GVA (+59%) and 1 400 job years (+24%) between 2008-2017;
- For the majority of contracted parties, implementing F4E contracts is seen as part of their core business through which they aim to make a profit. However, for a substantial minority of

the contracted parties, an F4E contract is regarded as a stepping stone towards realising longer term spin-offs and benefits;

- Among the key reasons for carrying out work on ITER is to boost a firms reputation as a leading high-tech company. For many firms they also have a positive appraisal of the indirect benefits outside of fusion and big science which a large majority also judge as having good potential for future financial growth;
- Thirdly, more than 1/3 of firms have developed new cutting edge technologies as a result of their work on ITER. Whilst only a handful of these have led to specific spin-offs this is a longer term process, and one could expect that these benefits will become more visible in future;
- Fourthly, around ¼ of firms that were surveyed reported that the work has helped them to access new business opportunities both inside and outside fusion. In this area the role of consortiums is important, with almost 40% of firms having worked as a consortium, most in a consortium of firms from more than one EU country, and many of these firms reporting synergies and new opportunities. In addition firms had a positive view on synergies in working on other Big Science projects as a result of their work on ITER;
- Finally, 85% of surveyed firms noted that working on ITER had required them to develop new knowledge and skills, with 25% substantially developing their knowledge and skills. The areas of engineering, and engineering and mechanical design were the most common areas for new developments.

Table 3-1: Dashboard impact indicators

Theme/ area	Proposed indicator	Summary impact to date	Estimated impact to 2030
Employment and growth in the EU28	Value added (GVA) contribution	**Cumulative 2008-2017:** €4 786 million (gross) / €132 million (net)[15] **2017 only:** €1 104 million (gross) / -€25 million (net) Potential additional benefit from spinoffs: €561 million (gross) / €78 million (net)	**Cumulative 2018-2030:** €15 900 million (gross) / €454million (net) **2030 only:** €795 million (gross) / €83 million (net) Potential additional benefit from spinoffs: €2 248 million (gross) / €449 million (net)
	Employment contribution	**Cumulative 2008-2017:** 34 000 job years (gross) / 5 800 job years (net) **2017 only:** 7 400 job years (gross)/ 600 job years (net) Potential additional benefit from spinoffs: 4 700 job years (gross) / 1 400 job years (net)	**Cumulative 2018-2030:** 72 400 job years (gross) / -1 100 job years (net) **2030 only:** 2 800 job years (gross) / 400 job years (net) Potential additional benefit from spinoffs: 10 900 job years (gross) / 2 300 job years (net)

[15] Gross values are in comparison to a baseline where the spending on ITER did not occur, Net values are in comparison to an alternative spending scenario reflecting the money being invested in the economy proportional to the share of the economy of each sector.

Theme/ area	Proposed indicator	Summary impact to date	Estimated impact to 2030
Innovation and technology transfer	New cutting edge-technologies (fusion related and beyond fusion)	28% of the survey respondents [in addition: 6% report spin-outs and 36% the development of new process related technologies]	No information
New business opportunities	In general	27% of the survey respondents	57% of the survey respondents
	New spin-off products outside fusion	0% of the survey respondents [although in the open answers examples of new products are given]	19% of the survey respondents
	New markets outside fusion	15% of the survey respondents	28% of the survey respondents
Knowledge and skills development	New knowledge acquired and/or new skills developed	85% of the survey respondents [of which 62% to a limited extent and 23% to a substantial extent]	No information

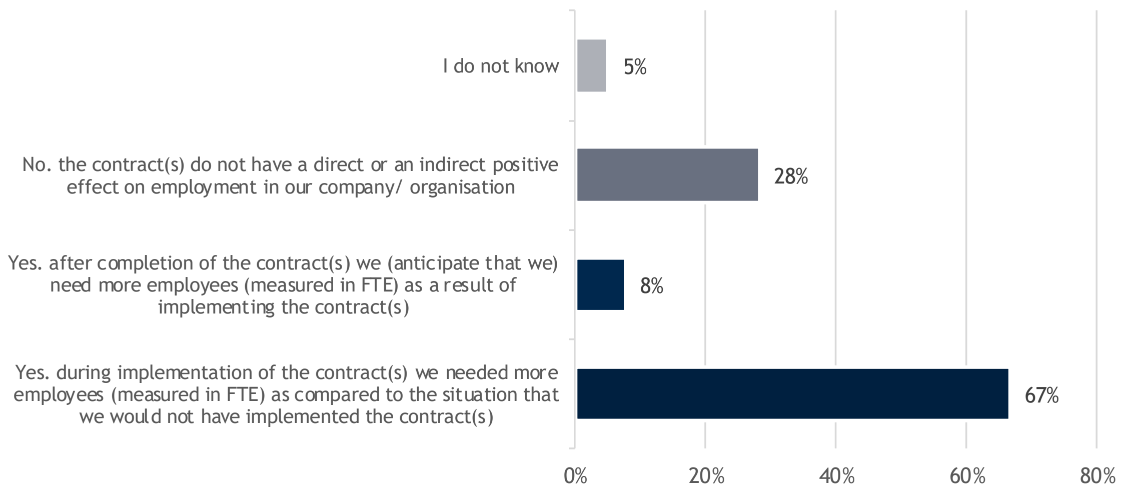
3.2. Employment and growth

3.2.1. Economic impact - survey results

In the survey we asked about the impact of implementing ITER contracts on employment in the short-term (during implementation of the contract) and the medium to long term (after completion of the contract). Only 39 respondents responded to this question and hence we should regard the results (see Figure 3-1) as indicative.

It appears that in 67% of the cases there was at least a temporary employment effect: more employees were needed during contract implementation. A longer term employment effect as a result of a permanent rise in production was reported by 8% of the respondents.

Figure 3-1: Did the implementation of the contract(s) have an impact on employment in your company/ organisation? (n=39)



Source: Stakeholder survey

When asked about how to divide the effect on employment between lower skilled employment and higher skilled employment, the 13 responses obtained suggested a division of ca. 20% (lower skilled labour) and 80% (higher skilled labour). This points to the majority of jobs, even with ITER at a construction stage, requiring high skills.

The survey suggests that the employment impacts of work on ITER are linked closely to contract implementation and that the end of the contracts could lead to the jobs coming to an end, e.g. a more short term than long term employment effect. The feedback from the case studies (see Annex A) suggests rather that even if the intention was short term companies have in reality experienced significant growth and have taken (and kept) people on, growing the number of people employed on fusion, with examples of 25 new high skilled position in a growing team (case study 6) and a fusion team growing from 2 people in 2005 to 15 today as a result of work on ITER (case study 9). This is no guarantee that the jobs are permanent, but is strongly suggestive of a longer term perspective on employment growth. In our opinion there will be significant sustainability of this employment impact beyond the contract duration, as staff to continue to work in the fusion area or on the other applications directly resulting from and related to their work on fusion.

3.2.2. Economic impact – results of E3ME-based modelling approach

The E3ME model was also applied to provide a detailed assessment of the impact on employment and gross value added (GVA) of the ITER project activities in the EU over the period 2008-2017. As a macro-econometric model, E3ME is already based on an extensive historical database and was thus well placed to carry out this ex-post economic analysis. E3ME is regularly used for policy analyses for the European Commission and other public and private clients, and is a trusted economic analysis tool[16].

The high sectoral and regional disaggregation in the E3ME model's classifications allow for a detailed analysis of the impact of ITER investment within each Member State and across all 69 economic sectors. For this part of the analysis we consider the gross impacts of the ITER project activities, i.e. what was the impact on jobs and growth compared to not making this investment at all. We also consider the net impacts of the investment, i.e. what was the net benefit of investing in ITER project activities compared to spending the equivalent amount on a more general investment programme. A more detailed description of the E3ME model and the methodology applied to this modelling task, as well as a full description of the scenarios modelled, can be found in Annexes D and E.

In summary, the results presented below show that the gross impact of ITER-related investment (totalling €5,125 million between 2008-2017) is positive for employment and GVA. During the period 2008-2017 the model estimates that new jobs are created each year, increasing over time with an increasing amount of investment. In total, 34,000 job years[17] are created, mainly in construction, industry, non-business services and business services. The gross GVA results follow the same trends over time, with a cumulative total of €4 786m additional GVA generated between 2008 and 2017, in the same key sectors.

[16] https://www.camecon.com/how/e3me-model/
[17] Job years are used as it is the case that spending to create a job in one year may not sustain the job over time, therefore we can conclude only that a job is created for that year – a job year.

The net impacts are small, but positive, with greater impacts on employment and GVA occurring after 2011. In total, 5,800 jobs are created between 2008 and 2017, with the majority of these jobs occurring in non-business services. The cumulative net impact on growth is an increase of €132m in GVA over this time period, again, mostly occurring in non-business services.

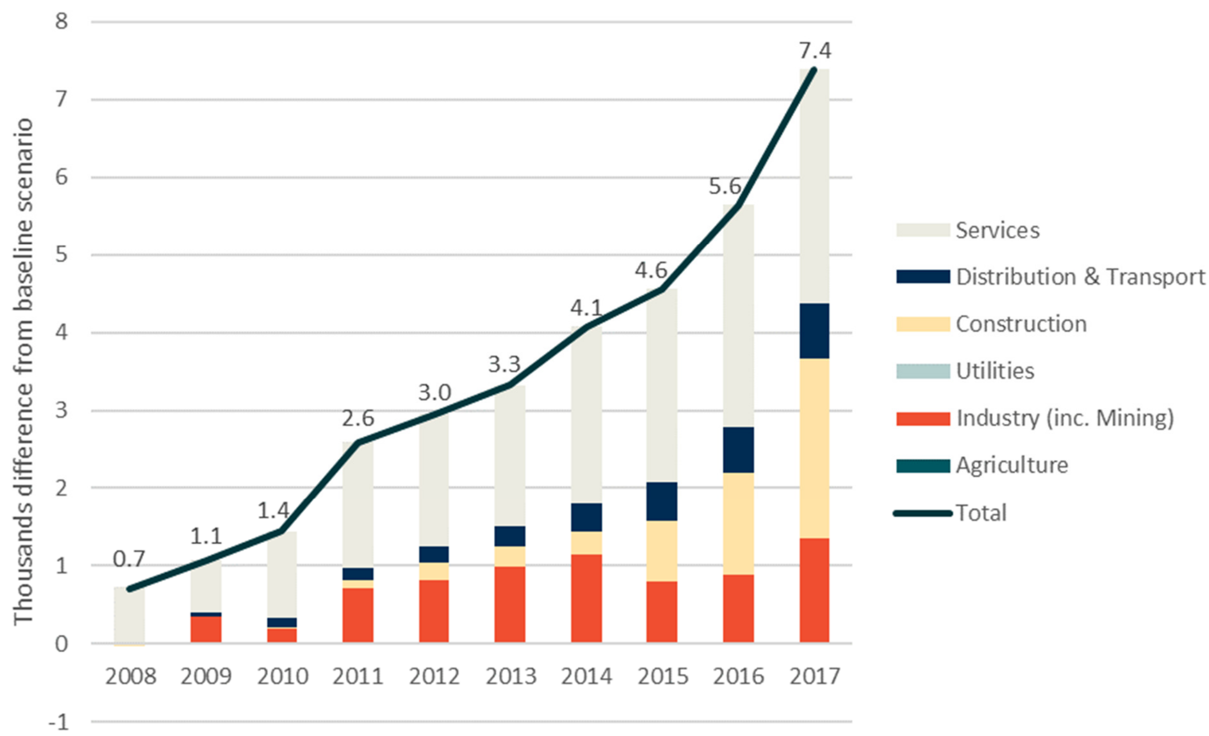
Employment

Gross impact scenario

First, we consider the gross employment impact of investment surrounding ITER activities. Under this scenario we assume that instead of this investment being made, the money is saved, and is therefore treated as a leakage from the economy (see Annex D for a more detailed scenario description). For ease of interpretation, the inverse of the results are presented, i.e. we show the benefits of spending on ITER compared to saving the money. Figure 3-2 and Table 3-2 below show employment results for the EU28 as a whole under this scenario. The proportional impact on employment is small (<0.01% of total EU28 employment), so the results are presented as absolute differences from the baseline.

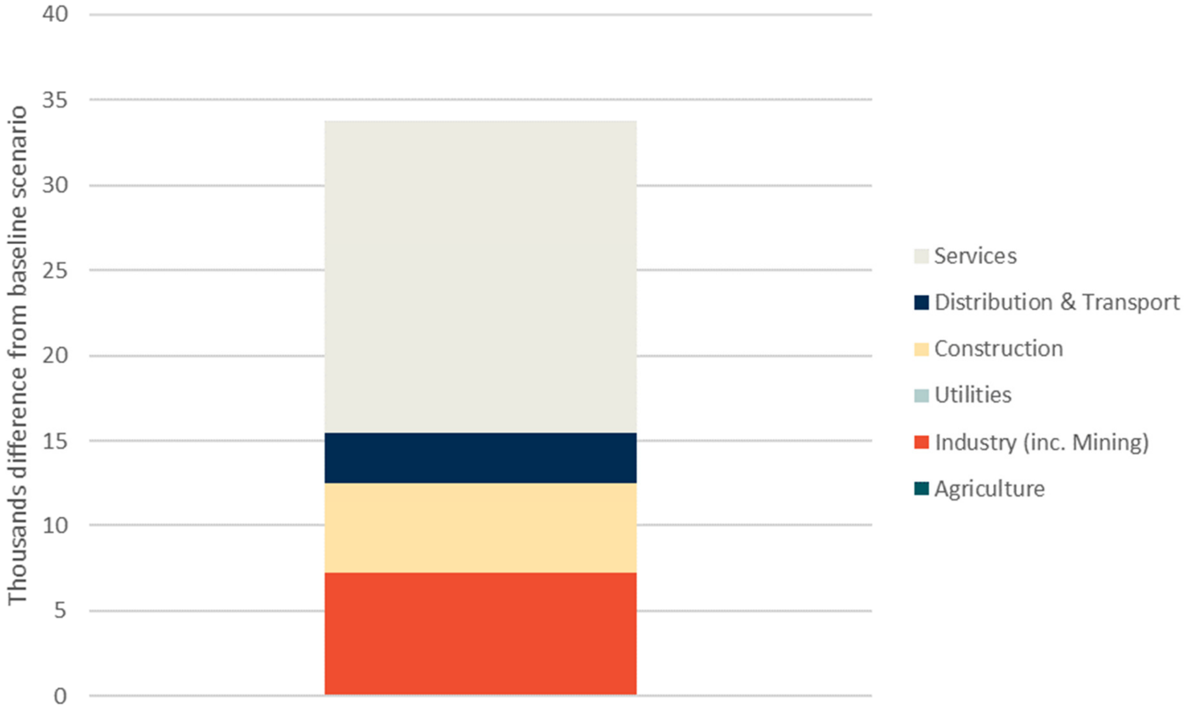
The model results show that ITER-related investments had a small positive impact on employment figures over the period 2008-2017, with this impact increasing over time in line with an increasing amount of investment. In 2017, 7,400 job years were created within the EU28 as a result of the investment. A large proportion of these jobs were created within the construction sector (2,300), with the industry, business services and non-business services sectors also seeing large increases in jobs (1,400, 2,100 and 900 respectively). Over the full period a total of almost 34,000 job years are created by the F4E spending on ITER-related contracts in Europe (see Figure 3-3).

Figure 3-2: Total EU28 impact on employment of the ITER programme, 000's difference from baseline



Sources: E3ME, Cambridge Econometrics.

Figure 3-3: Cumulative total EU28 impact on employment of the ITER programme, 000's difference from baseline



Sources: E3ME, Cambridge Econometrics.

<u>Differences across Member States</u>

During the period 2008-2017 a large proportion of investment occurred in the construction sector. France is the biggest beneficiary in terms of job creation in construction. The relatively large increase in employment in the construction sector across the EU28 reflects the fact that the ITER project was in an intensive construction phase in the period 2008-2017, with large amounts of resources going in to the initial phases of preparing the site, power supply works and construction of buildings at the ITER site in southern France. The ITER Organization previously estimated that construction of the ITER scientific facility would create up to 2,300 jobs at the site in France alone, with approximately 2,000 workers being needed at the height of the assembly activities. Other construction jobs are created as a direct result of ITER investment in other parts of Europe as contracts were awarded to companies in Germany, Ireland, Portugal, Romania, Spain and the UK for design and construction contributions to the ITER project site. These include a large contract awarded to a German company for the construction of cranes and their related infrastructure for the tokamak machine, and another large contract awarded to a Portuguese company for the assembly of steel structures for various facility buildings.

During this period a large proportion of investment also occurred in the non-business services sector. Spain receives the majority of investment in this sector, due to the location of the F4E offices in Barcelona. This investment, along with other investment in construction, industry and business services, leads to Spain being the largest beneficiary in terms of job creation between 2008-2017, with 13,400 job years created over the time period. Clearly the staffing at the F4E office, of around 400, over multiple years contribute significantly to the total for Spain. France is the second largest beneficiary, with around 10,700 job years created. Full country results can be found in Annex F.

Differences across sectors

In 2017, 2,100 jobs were created in the broad business services sector as a result of ITER-related activities. This sector includes legal & accounting services, architectural & engineering services, R&D and security & administration services; all of which were allocated a significant proportion of the non in-kind expenditures of F4E, leading to a direct impact on jobs in these sectors. However, these sectors also feature in the supply chains of the construction and industrial sectors that supply the in-kind investments, and so there are a large number of indirect jobs included within this figure (see Table 3-2).

The broad industrial sector includes both basic manufacturing sectors such as metals, and more advanced manufacturing activities, including computers, electrical equipment and other machinery. Large amounts of ITER-related investment contributed to output in these sectors between 2008 and 2017, covering the manufacture of technological components for the tokamak machine, the different plant systems that are necessary for the machine's operation and other surrounding buildings at the facility responsible for heating and ventilation and power supply etc. This investment led to an overall increase in employment of 1,400 jobs in 2017. Companies within these sectors in Germany, Italy and Finland received large shares of the contracts and grants over this time period, leading to these countries also being some of the biggest beneficiaries in terms of job creation in the EU28. As with business services, these industrial and manufacturing sectors also feature in the supply chain to the construction sector, supplying products such as metal beams, piping, electrical equipment and other building materials. There will therefore be an indirect positive impact on jobs within these sectors as a result of increased demand for these types of products from the construction sector (see Table 3-2).

The direct and indirect employment impact of ITER-related investments lead to greater disposable incomes for those workers employed, and therefore higher consumption. Higher consumption leads to an induced impact on employment as certain sectors related to consumer spending, such as retail, entertainment and sporting activities, see an increase in demand. The results from the E3ME modelling show that these induced impacts are in general small but not negligible. For example, in the distribution and retail sector around 400 additional jobs were created in 2017. The balance between the direct and indirect+induced effects are broadly the same across the years, namely that for every job directly created by ITER spending approximately 1.5-2 indirect or induced jobs are created.

Table 3-2: Total EU28 impact on employment of the ITER programme, 000's difference from baseline

Sector	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	Total job years
Agriculture	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1
Mining & Industry	0.0	0.4	0.2	0.7	0.8	1.0	1.1	0.8	0.9	1.4	7.1
Utilities	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Construction	0.0	0.0	0.0	0.1	0.2	0.3	0.3	0.8	1.3	2.3	5.3
Disribution & Transport	0.0	0.1	0.1	0.2	0.2	0.3	0.4	0.5	0.6	0.7	3.0
Services	0.7	0.7	1.1	1.6	1.7	1.8	2.3	2.5	2.9	3.0	18.3
Total	**0.7**	**1.1**	**1.4**	**2.6**	**3.0**	**3.3**	**4.1**	**4.6**	**5.6**	**7.4**	**33.8**

Sources: E3ME, Cambridge Econometrics. Note: totals may not sum exactly due to rounding.

Table 3-3: Direct and indirect/induced jobs from ITER programme, 000's difference from baseline, in year 2017 only

Sector	Direct	Indirect + Induced
Agriculture	0.0	0.0
Industry (inc. Mining)	0.7	0.7
Utilities	0.0	0.0
Construction	1.5	0.8
Distribution & Transport	0.0	0.7
Services	0.7	2.3
Total	**2.5**	**4.8**

Sources: E3ME, Cambridge Econometrics.

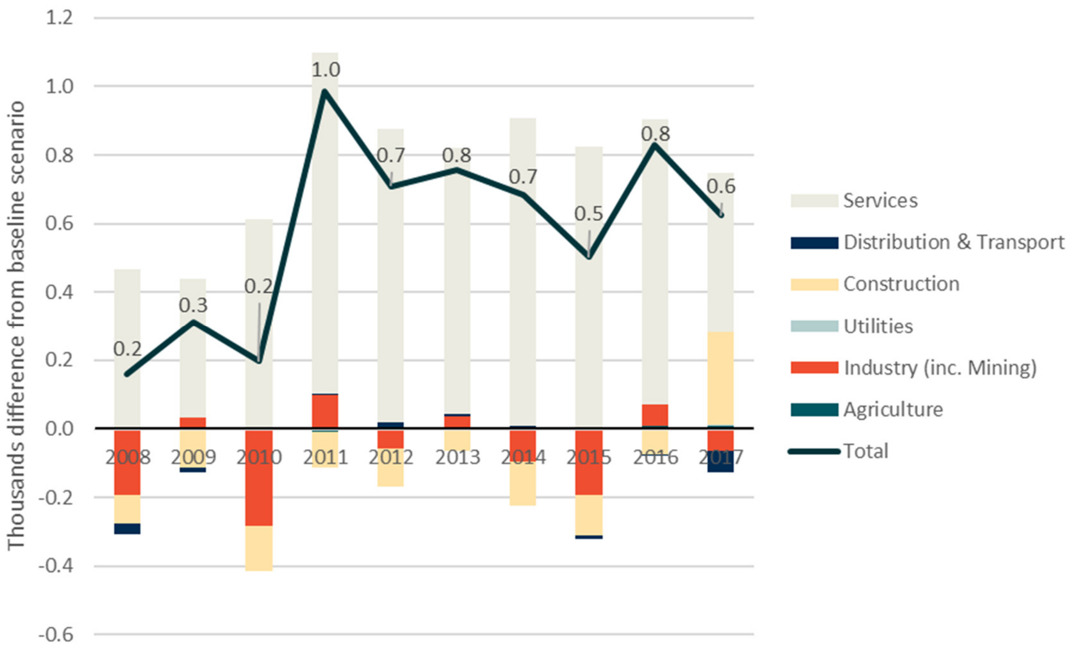
Net impact scenario

Next, we consider the net employment impact of investment surrounding ITER activities. Under this scenario we assume that the investment money spent on ITER activities would instead have been spent on alternative investments, in order to assess the added benefit of the programme (see Annex D for a more detailed scenario description). The share of investment between Member States is unchanged, however, so the results only show the effects of re-allocating investment between sectors. For ease of interpretation the results in the tables in this section show the impacts of the ITER programme *instead of alternative investment*.

Figure 3-4 and

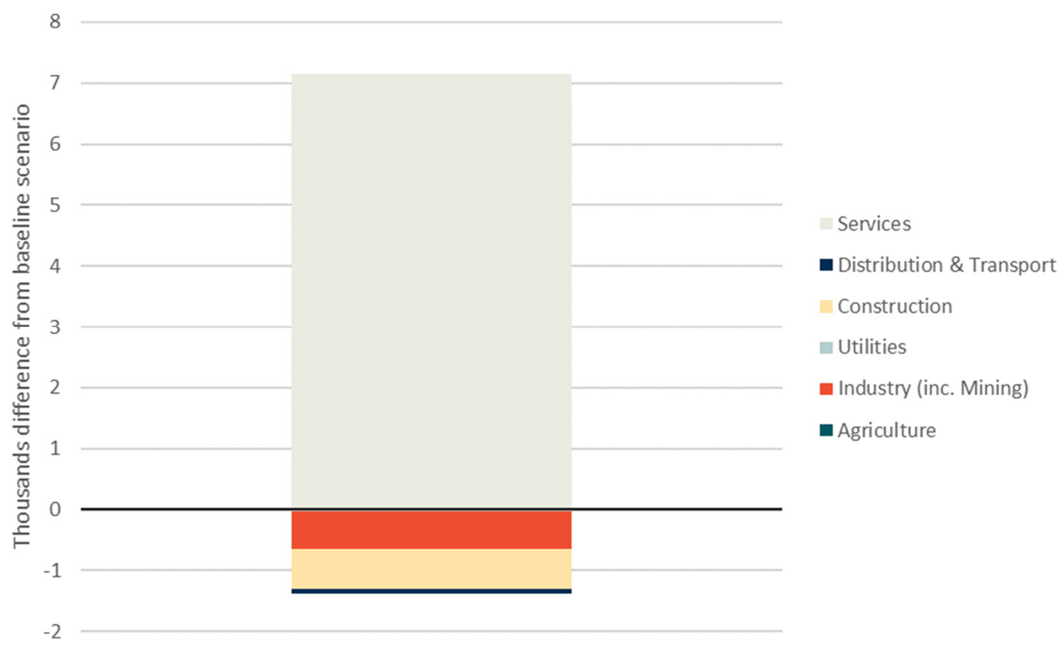
Table 3-4 below show employment results for the EU28 as a whole under this scenario. Naturally, the net impact on employment is smaller than the gross impacts presented in Figure 3-2 and Table 3-2, so again the results are presented as absolute differences from the baseline. The model results show that the effects of ITER instead of alternative investment are positive. The largest increases occur after 2011; around 500-1000 jobs are created each year between 2011 and 2017. The total net job years created over the full period are around 5,800 (see Figure 3-5).

Figure 3-4: EU28 impact of the ITER programme (rather than alternative investment) on employment, 000's difference from baseline



Sources: E3ME, Cambridge Econometrics.

Figure 3-5: Cumulative total EU28 impact on employment of the ITER programme, 000's difference from baseline



Sources: E3ME, Cambridge Econometrics.

There are more significant shifts in employment to note at sectoral level. Compared to the alternative investment programme, the ITER programme generates large increases in jobs in the non-business services sector, while the alternative spending scenario leads to a shift to more job creation in industry and construction. This finding makes intuitive sense as the ITER investment programme was highly focused on the manufacture of specialised equipment within the industry sector during the period 2008-17. A broader investment programme would have included greater investment in a wider range of equipment (as well as motor vehicles), leading to higher overall levels of investment in the industry sector compared to the ITER investment programme.

There are also some differences in the results at Member State level. The largest impacts are in the countries with the most investment (and hence the biggest shifts between sectors in this scenario). In Spain, France, Portugal and Poland, the ITER investment programme creates more jobs than alternative investments, whereas in Italy, Germany and the Czech Republic the number is smaller. The reasons for the differences relate to the different labour intensities of the sectors affected; the ITER programme will create more jobs in places where its investment is directed towards more labour intensive activities, and where more emphasis is placed on sectors that create greater indirect and induced effects. Detailed results tables can be found in Annex F.

Table 3-4: EU28 impact of the ITER programme (rather than alternative investment) on employment, 000's difference from baseline

Sector	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	Total job years
Agriculture	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Industry (inc. Mining)	-0.2	0.0	-0.3	0.1	-0.1	0.0	-0.1	-0.2	0.1	-0.1	-0.6
Utilities	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Construction	-0.1	-0.1	-0.1	-0.1	-0.1	-0.1	-0.1	-0.1	-0.1	0.3	-0.7
Distribution & Transport	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-0.1	-0.1
Services	0.5	0.4	0.6	1.0	0.9	0.8	0.9	0.8	0.8	0.5	7.1
Total	**0.2**	**0.3**	**0.2**	**1.0**	**0.7**	**0.8**	**0.7**	**0.5**	**0.8**	**0.6**	**5.8**

Sources: E3ME, Cambridge Econometrics. Note: totals may not sum due to rounding.

Table 3-5: Direct and indirect/induced jobs from ITER programme (rather than alternative investment), 000's difference from baseline, 2017

Sector	Direct	Indirect + Induced
Agriculture	0.0	0.0
Industry (inc. Mining)	0.0	0.0
Utilities	0.0	0.0
Construction	0.2	0.1
Distribution & Transport	0.1	-0.1
Services	0.6	-0.1
Total	-0.7	1.3

Sources: E3ME, Cambridge Econometrics. Note: totals may not sum due to rounding.

Economic growth

Gross impact scenario

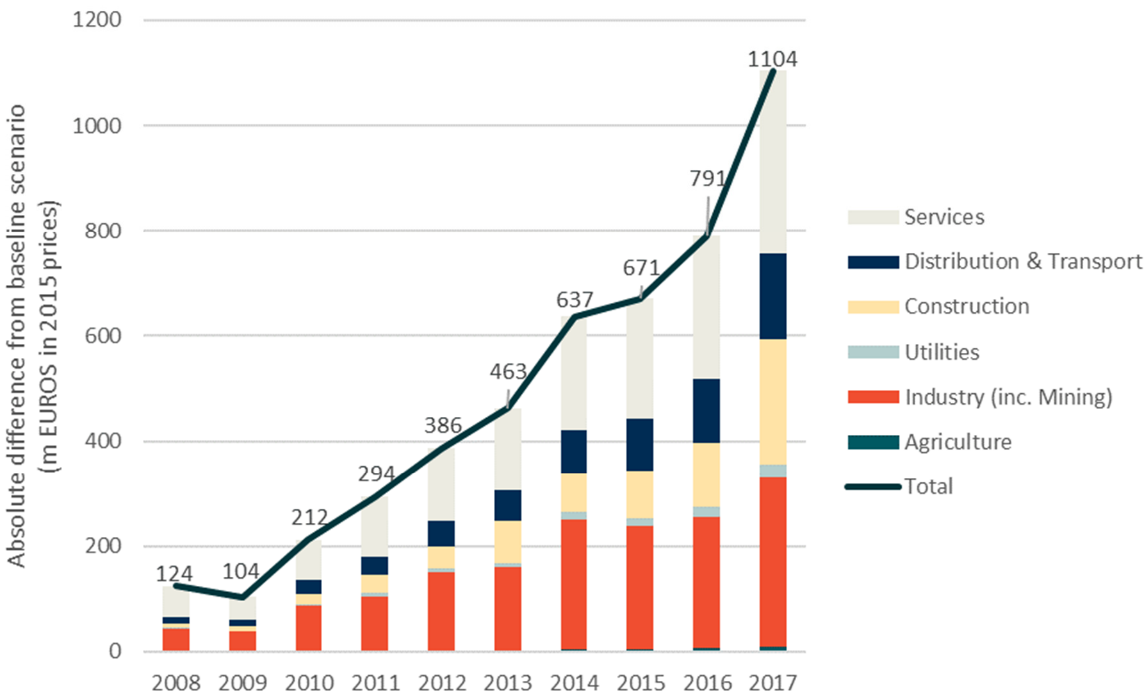
In order to assess the economic growth impacts of ITER related investment, we consider the gross value added (GVA) by sector. GVA is similar in concept to GDP but may be applied at a sectoral level. GVA comprises labour, profits and production taxes; it does not include intermediate purchases of inputs to production.

Figure 3-6 and Table 3-6 below show GVA results for the EU28 as a whole under this scenario. As with the employment impacts, the impact on GVA is small (<0.01% of total EU28 GVA), so the results are presented as absolute differences from the case in which the ITER programme does not take place (with no alternative spending). The cumulative total over the 2008-2017 period is for additional GVA of €4,786 million, which when compared to modelled inputs of €5,125million[18] represents a near-full recovery of the ITER spend[19]. The remaining value is attributed to activities outside the EU, i.e. through imported components.

[18] Total is calculated from known F4E payments of €4,509 million over the same period, plus expected payments of €616 million in the remainder of 2017.
[19] It should be noted that the actual economic output impact (including intermediate purchases – and more closely aligned to what may be thought of as turnover) is higher still, cumulatively between 2008-2017 at €11,670 million, representing a multiplier of around 2.3 per Euro spent. Similar ratios are found across all years.

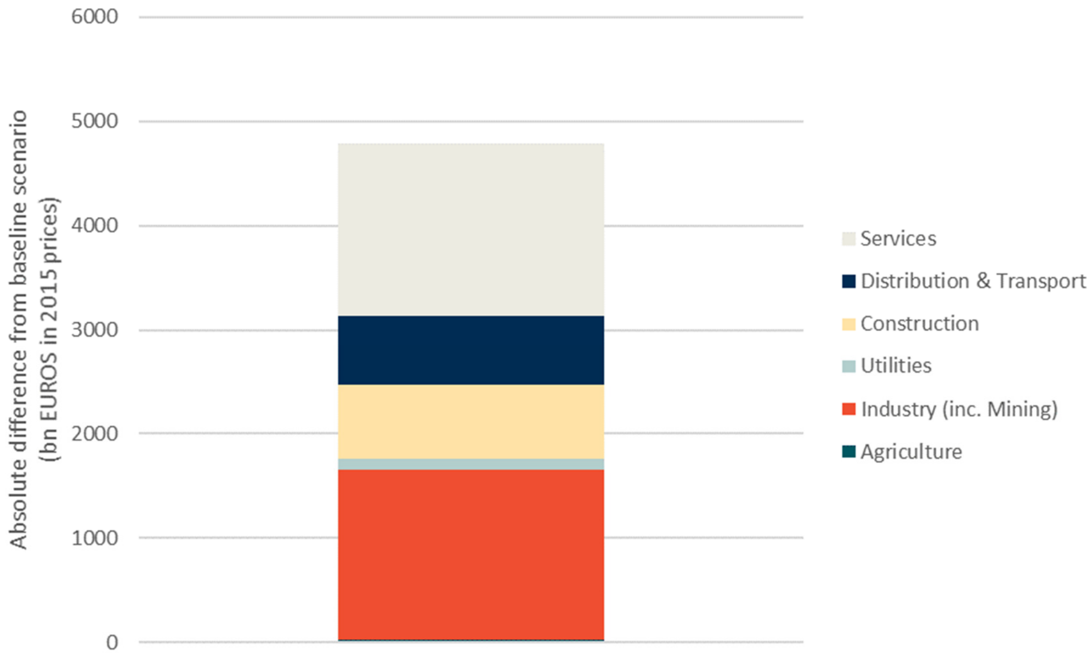
The positive impacts on GVA increase over time, in line with an increasing amount of investment (see Figure 3-6). In 2017 the EU28 produced an additional €1.1bn of GVA compared to the baseline, in which no investment takes place. In the same year, 43% of total ITER investment was spent on construction and 45% on industry; it is therefore unsurprising that these sectors contributed most to the overall GVA increase. However, all sectors across the economy benefitted from the large investments in these sectors due to interdependencies within supply chains. While the construction and manufacturing sectors received the greatest shares of investment over the period 2008-2017, supply-chain effects benefit other industrial sectors and (particularly) business services (Figure 3-6). The table (3-7) also demonstrates that the ratio between direct and indirect+induced economic impact is significant, €379 million, to €725 million, or that for every € of GVA generated directly a further €1.9 is generated elsewhere. This ratio remains quite similar over time.

Figure 3-6: EU28 impact of the ITER programme on GVA, absolute difference from baseline (m 2015 €)



Sources: E3ME, Cambridge Econometrics.

Figure 3-7: Cumulative EU28 impact of the ITER programme on GVA, absolute difference from baseline (m 2015 €)



Sources: E3ME, Cambridge Econometrics.

As with the employment results, the countries which see the greatest impact on GVA are those in which the highest shares of ITER investment were spent. These include France (€1,336 million GVA increase) and Spain (€459 million), in which large amounts of construction and non-business services investment took place to build the ITER scientific facility, and for hosting the scientific facility and F4E offices. Germany (€255 million GVA increase) and Italy (€345 million) also receive high shares of total EU investment and consequently GVA benefit. In these Member States manufacturing companies were awarded large contracts and grants to develop components and technology for the tokamak facility. Detailed results are presented in Annex F.

Table 3-6: EU28 impact of the ITER programme on GVA, absolute difference from baseline (m 2015 €)

Sector	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	Total cumulative
Agriculture	1	1	1	1	2	2	4	5	6	9	32
Industry (inc. Mining)	44	37	85	103	148	157	247	232	250	323	1625
Utilities	2	2	4	6	8	9	15	16	19	23	103
Construction	6	9	19	35	43	79	72	89	121	239	713
Distribution & Transport	13	12	26	35	47	58	83	100	122	162	658
Services	58	45	77	113	139	157	216	230	272	348	1655
Total	**124**	**104**	**212**	**294**	**386**	**463**	**637**	**671**	**791**	**1104**	**4786**

Sources: E3ME, Cambridge Econometrics.

Notes: The sum of changes is in real terms but not otherwise discounted.

Table 3-7: Direct and indirect/induced GVA impacts from ITER programme, m 2015 € difference from baseline, year 2017 only

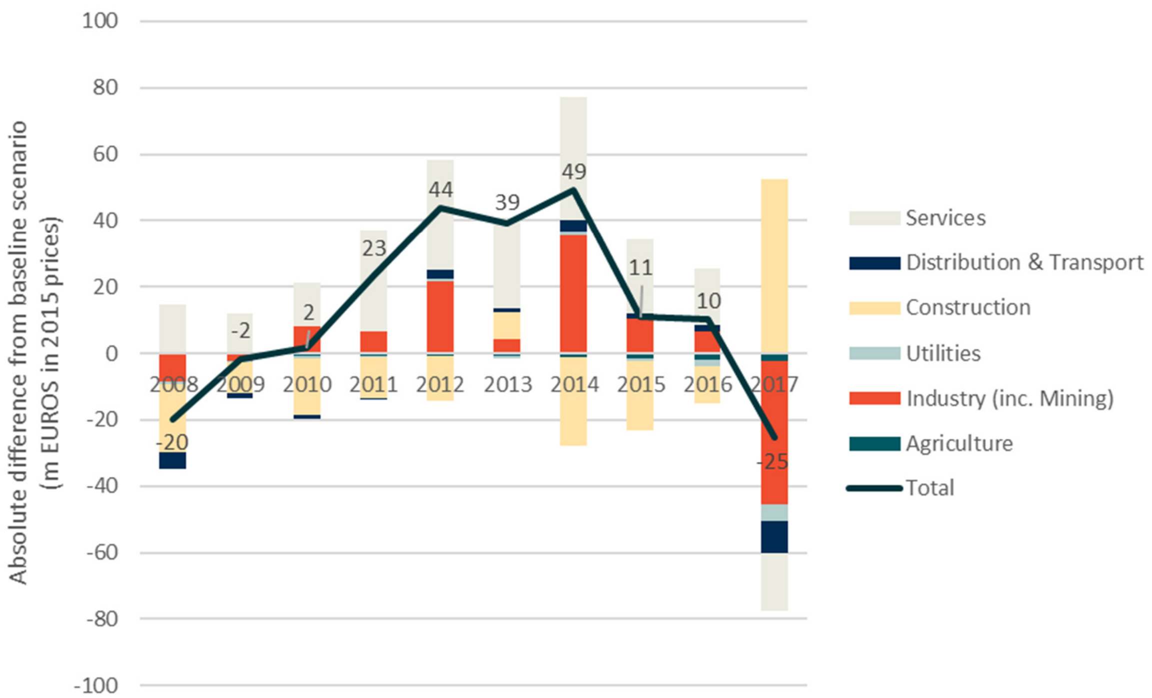
Sector	Direct	Indirect + Induced
Agriculture	0.0	8.8
Industry (inc. Mining)	155.4	167.2
Utilities	0.0	23.3
Construction	159.2	80.1
Distribution & Transport	5.1	156.7
Services	59.4	288.8
Total	**379.1**	**724.9**

Sources: E3ME, Cambridge Econometrics.

Net impact scenario

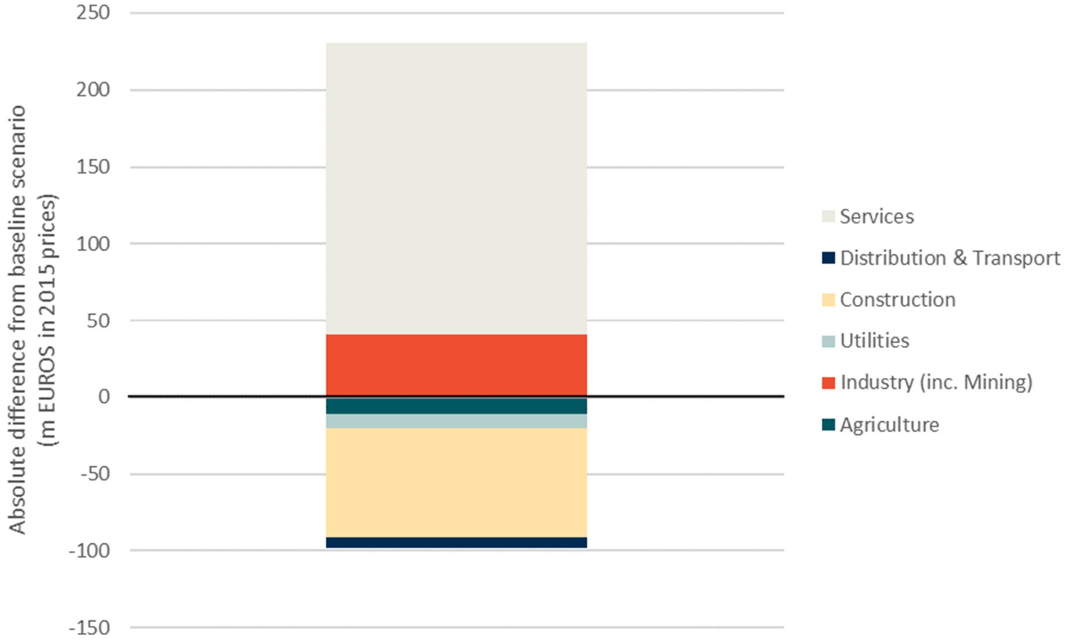
Figure 3-8 and Table 3-8 below present the impact on GVA for the EU28 as a whole, again comparing the impact of the ITER programme against an alternative programme of investment. The findings are sometimes ambiguous. Generally over the period 2008 to 2017 total GVA is higher when investment is spent on ITER-related investments, whereas at the start of the period and in 2017, GVA is lower. However, it should be noted that overall these impacts are small (<+/-€50m). The cumulative net GVA impact is estimated at €132 million over the full period, a positive net impact.

Figure 3-8: EU28 impact of ITER (rather than alternative investment) on GVA, absolute difference from baseline (m 2015 €)



Sources: E3ME, Cambridge Econometrics.

Figure 3-9: Cumulative EU28 impact of ITER (rather than alternative investment) on GVA, absolute difference from baseline (m 2015 €)



Sources: E3ME, Cambridge Econometrics.

Across countries (see Annex 4 - Table F-4 for detailed results), the overall impact on GVA by Member State is small. The changes reflect the way the investment is spread under the different programmes (remembering that, under the alternative investment programme, total investment is the same as with ITER in each country). If the investment is targeted at high value-added sectors (such as services) then the impact on GVA is larger (such is the case in Spain and Poland). Where the investment is targeted at lower value-added sectors (such as construction), and particularly sectors that use a large share of imported materials, the overall impact on GVA is smaller (such as in France, Germany and Italy). Full results per country can be found in Annex F.

As with the net employment results, the differences between sectors are more noteworthy. When investment is focused on ITER-related activities, the largest beneficiary during this time period is the non-business services sector, which receives a large share of ITER investment in this initial start-up phase of the project (primarily in F4E related administration). This positive impact on total GVA is offset somewhat by negative impacts on GVA within business services and construction. In all years the results show that the direct growth impacts of the ITER investment are larger than the direct impacts of an alternative spending programme, €27.9 million in 2017. However, an alternative spending programme would allocate a greater proportion of investment to business services and a wider range of manufacturing sectors. This leads to greater indirect growth impacts compared to the ITER investment programme as a result of greater indirect and induced impacts through the relevant supply chains and increased consumption, see Table 3-9. This table shows that the indirect and induced impacts in 2017 are around twice as big as the direct effects, in this case in opposing proportions, where the direct impact of ITER spending generates almost two times less indirect and induced GVA than the alternative, around (minus) -€53 million in 2017.

Table 3-8: EU28 impact of ITER (rather than alternative investment) on GVA, absolute difference from baseline (m 2015 €)

Sector	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	Total cumulative
Agriculture	0	0	-1	-1	-1	-1	-1	-1	-2	-2	-11
Industry (inc. Mining)	-8	-2	8	6	22	4	36	10	7	-43	41
Utilities	-1	-1	-1	0	1	-1	1	-1	-2	-5	-9
Construction	-20	-9	-17	-12	-13	8	-27	-21	-11	53	-71
Distribution & Transport	-5	-2	-1	-1	3	1	3	2	2	-10	-7
Services	15	12	13	31	33	27	37	22	17	-18	190
Agriculture	0	0	-1	-1	-1	-1	-1	-1	-2	-2	-11
Total	**-20**	**-2**	**2**	**23**	**44**	**39**	**49**	**11**	**10**	**-25**	**132**

Sources: E3ME, Cambridge Econometrics.

Notes: The sum of changes is in real terms but not otherwise discounted.

Table 3-9: Direct and indirect/induced GVA impacts from ITER programme (compared to alternative investment), m 2015 € difference from baseline, year 2017 only

Sector	Direct	Indirect + Induced
Agriculture	-1.7	-0.7
Industry (inc. Mining)	-14.2	-28.7
Utilities	-4.8	-0.3
Construction	37.2	15.4
Distribution & Transport	4.0	-13.6
Services	7.4	-25.0
Total	**27.9**	**-53.0**

Sources: E3ME, Cambridge Econometrics.

Additional impact of spin-offs

As the following sections 3.3-3.6 discuss, future ITER contracts are likely to lead to further technological spin-offs and new business opportunities for European firms. These spin-offs may improve productivity and subsequently lower costs within certain sectors, or new markets may develop. This would result in higher GVA and further investment in future years in addition to the increase in GVA generated directly by ITER contracts, but this additional growth is not captured in the model results. The survey carried out in this study provided evidence of some spin-offs that could be attributed to ITER investment, and some indication about the number of firms that may experience such spin-offs. In order to consider the likely further impacts on employment and GVA, a further calculation was carried out on the initial increase in GVA reported by the E3ME model, to make a high-level assumption about how much additional investment spin-offs may generate. As a simple exercise to provide an indication of this impact, this additional investment was added back into the model to determine the specific employment and growth impacts of spin-offs (for a more detailed description of this additional model run, please see Annex D).

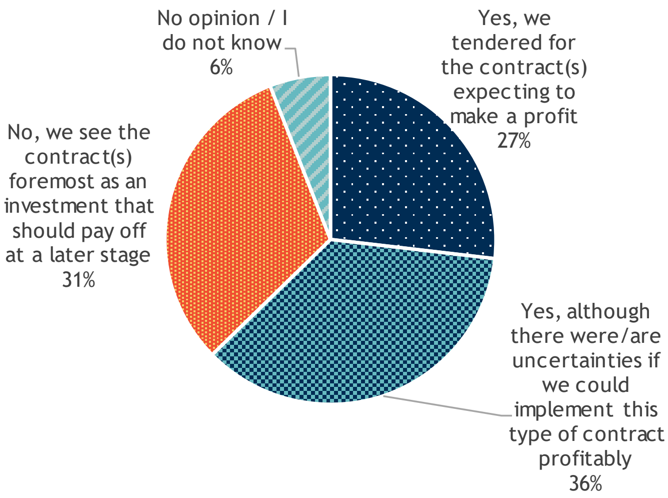
The gross impact results show that spin-offs may generate an extra 4,700 jobs between 2008 and 2017 and an increase in GVA of €561m over this period. In order to consider the net benefit of spin-offs from the ITER investment programme, we compare this to the spin-off impacts of an alternative investment programme. ITER investment is found to generate an additional 1,400 job years and €78m in GVA between 2008 and 2017.

3.3. Why are contracted parties interested in implementing ITER contracts?

Before we turn to the further description of the economic effects, it is interesting to look at the motivation of contracted parties to acquire and implement ITER contracts. For example, spin-offs in one or other form could emerge as an unexpected side effect, but it could also be one of the aims of the contracted party at the outset.

From Figure 3-10 it can be seen that the majority of the contracted parties indicate that implementing the contract is important to the profitability of the organisation (63%), while a significant minority (31%) regarded the contract as in investment that should pay off at a later stage.

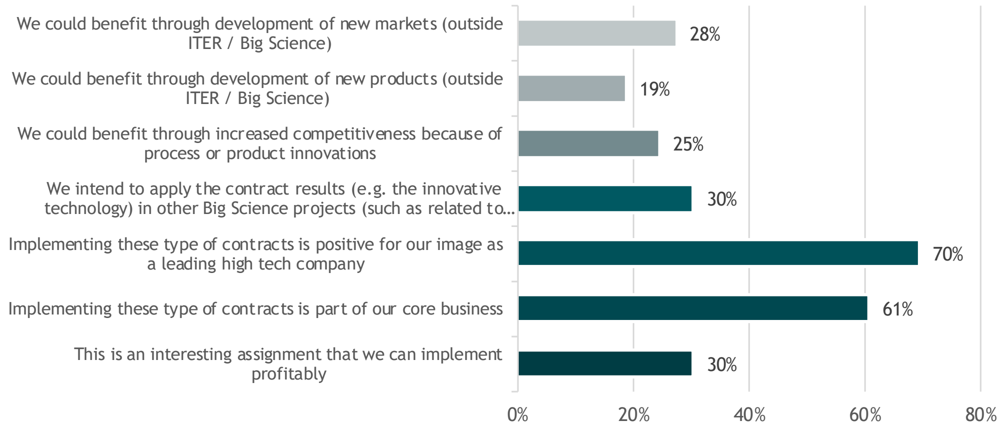
Figure 3-10: Is implementing the contract important for the profitability of your organisation? (n=67)



Source: stakeholder survey

Taking the same issue from a somewhat different angle, we have also asked what the contracted parties expect to achieve from implementing (the) ITER contract(s) (see Figure 3-11). The answers chosen most often are 'Implementing these type of contracts is positive for our image as a leading high tech company' (71%) and 'Implementing these type of contracts is part of our core business' (62%).

Figure 3-11: Why is your organisation implementing F4E contracts? (n=69)



Source: stakeholder survey

From the data underlying the figure there were 39 unique respondents (57% from 68) that pointed at the potential importance of any positive indirect effects of having implemented the contract(s). These positive indirect effects could be derived in future because of the development of new markets (outside ITER / Big Science, mentioned by 28% of the respondents), increased competitiveness because of process or product innovations (25%), and/or the development of new products (outside ITER / Big Science; 19%).[20]

Out of the 39 respondents that pointed at the potential importance of any positive indirect effects, 38 answered the question 'Do you expect that your organisation will experience financial growth as a result of these benefits from having implemented the F4E contract?' 26 respondents see opportunities for financial growth, while six do not and another six do not know. If we relate the 26 to the 68 unique respondents, this means that 38% of the respondents see opportunities for financial growth, which can be divided into 9% (substantial growth), 9% (moderate growth) and 21% (some growth).

All in all, one can conclude that for the majority of contracted parties, implementing ITER contracts should be seen as part of their core business through which they aim to make a profit. However, for a substantial minority of the contracted parties, an ITER contract is regarded as a stepping stone towards realising longer term spin-offs and benefits. In any case firms also expect to improve their reputation as a high tech firm through implementing work on ITER. The case study examples bear this out, with this helping with attracting high skilled recruits (for example case studies 4 [see box text below] and 7), building a reputation which contributes to opportunities in new markets (for example case studies 6, 8 and 10).

Case study example (No. 4) - Pro-beam: working on ITER boosting reputation and ease and quality of recruitment

Increased attention from the regional and national press due to Pro-beam's involvement in ITER has also helped to raise pro-beam's profile with engineers. This has significantly helped the company in the hiring process. Over 20 people have been hired by pro-beam as a result of their work on F4E contracts. These employees focus solely on fusion-related work and are generally technicians and engineers – some of which hold a Ph.D.

3.4. Innovation and technology transfer

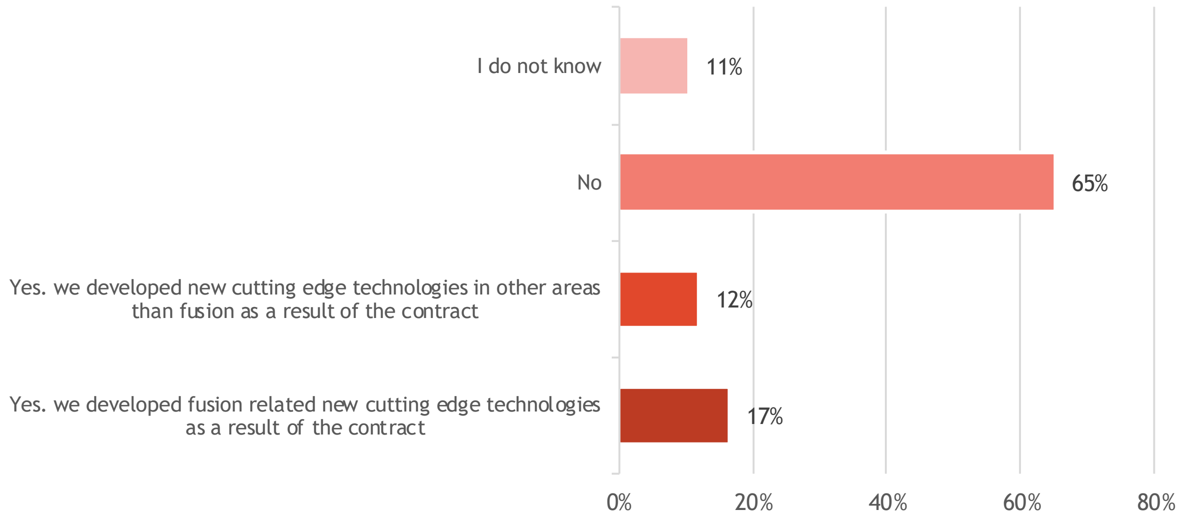
It is interesting to see to what extent these expected longer-term spin-offs and benefits have materialised already. With regard to innovation, Figure 3-12 shows whilst most respondents (65%) did not develop cutting edge technologies, a significant minority did. Around 17% of respondents developed new cutting-edge technologies in the fusion area, and 12% developed new cutting-edge technologies in areas other than fusion as a result of their F4E ITER contract(s). Among the specific examples given were the following:

- "Specific welding procedures";
- "Special materials bonding techniques";
- "New methodologies and infrastructure for Computational Fluid Dynamics (CFD) and advanced mechanical analysis";

[20] Note that multiple answers were possible and that these percentages exceed the 57% of unique respondents.

- "We are developing state-of the-art capabilities in the general fields of structural dynamics and seismic engineering that we are starting to apply to other sectors";
- "Manufacturing coils using cable-in-conduit, niobium-tin-based conductor technology;"
- "Diagnostics for low temperature plasma applications; engineering of custom sensors and detectors and related electronics";
- "Magnetic sensors based on low temperature co-fired ceramic (LTCC) technology";
- "Advanced use of the fast transient software EUROPLEXUS for seismic-induced impact between large components".

Figure 3-12: Have you developed new cutting-edge technologies as a result of the contract(s)? Multiple answers possible. **(n=66)**



Source: stakeholder survey

Out of the 66 respondents that answered the question 'Has the implementation of the contract(s) given rise to (or will it give rise to) setting up a company (spin-out) to further develop and commercialise the technology?' three respondents indicated that this was the case and one respondent indicated that this has not happened yet, but that they are considering establishing one or more companies for that purpose. 56 respondents answered 'no' to this question while 5 did not know. Hence, the number of spin-outs as a result of ITER seems to be rather limited so far (6% of the survey cases). An interesting example of one of these spin-outs is presented in the following textbox.[21]

Case study example (No.2) MAGICS Instruments NV (spin-out)
An interesting example of a spin-out is the Belgian company MAGICS Instruments NV, set up in October 2015 with KU Leuven and SCK•CEN (the Belgium Nuclear Research Centre) as shareholders. This spin-out is a direct result of an ITER project awarded by F4E to a research group from KU Leuven and SCK•CEN to further develop hardened integrated circuits capable of resisting high radiation environments, a key challenge that was identified and included in the Euratom Fusion Technology Programme in the 1990s. MAGICS' core competence lies in the design of radiation hardened integrated circuits, and more specifically in electronic devices that reliably operate in space and nuclear environments. MAGICS addresses customers' demands by offering ASIC solutions, customised IC design services or rad-hard IP

[21] This spin-out is further described in one of the case studies and was not mentioned in the survey.

licensing. Having started with the two founders, the company currently has five employees.

While around 50% of MAGICS' revenue still comes from ITER contracts, the company has managed to gain a share in several markets where radiation hardened sensors can be useful, e.g. space and nuclear fission. The size of the hardened-circuit markets amounted to roughly USD 1bn in 2015.

Non-ITER clients of MAGICS are not to be disclosed, but could be found in the area of service suppliers (engineering firms) to nuclear power plant operators. The company's products outside ITER mainly facilitate remote handling for nuclear reactors and nuclear waste management. MAGICS' products also find applications in the space sector.

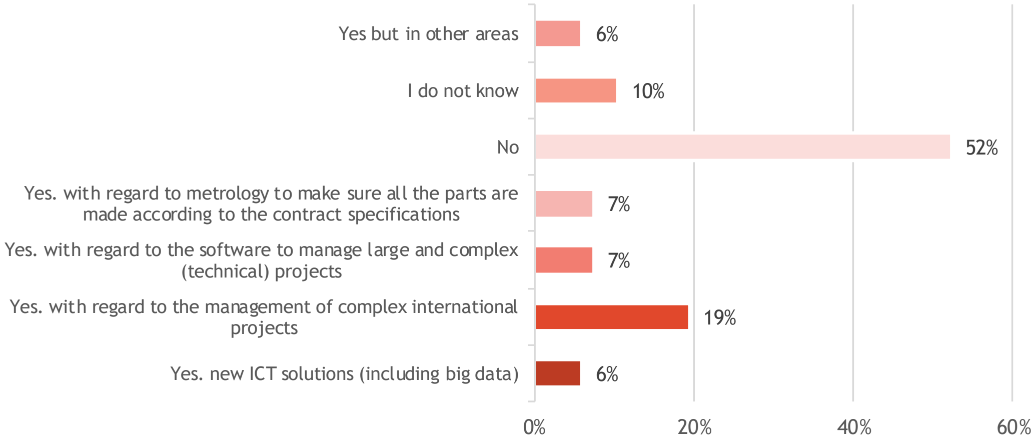
MAGICS are seeking to increase their revenues to €1M in 2018 and to €3M in 2020. The main goal for 2018 is to venture into emerging markets (Russia, India, China). The company is currently setting up distribution and sales channels in these countries to make market entrance possible. MAGICS is also looking for further business opportunities in the space market, in particular with emerging new commercial providers such as SpaceX.

The ITER contracts are very important for MAGICS' network and references. Big Science projects such as ITER are 'early technology adopters'. This helps SMEs like MAGICS to design and improve their product in an incubator phase. ITER also serves as a 'Lighthouse Project' for MAGICS, providing the company with a significant reputational boost in the industry and toward potential clients. The execution of the ITER contracts helps prove to potential clients that the technology works and that it can be applied.

As can be seen in Figure 3-13, by taking away the No and Don't Know answers, then it can be determined that around 38% of the respondents developed new process-related technologies. This is mostly connected to technologies with regard to the management of complex international projects (19%) and to a lesser extent to the development of software to manage large and complex (technical) projects (7%), new ICT solutions (6%) and metrology[22] (7%).[23] Under 'other areas', four areas were mentioned once: (1) numerical simulations techniques, (2) special manufacturing processes, (3) structural dynamics and seismic engineering and (4) to execute structural analysis, CFD analysis, seismic analysis.

[22] The science of weight and measures
[23] Note that multiple answers were possible so that the figures add up to more than 100%.

Figure 3-13: Have you developed new process-related technologies linked to the implementation of the F4E contract(s)? (n=67)



Source: stakeholder survey

In summary, and based on our experience, we conclude that working on ITER is encouraging contracted firms to innovate. Although the innovation may 'only' be a process innovation, or not be at what they regard as the cutting edge, (although in around 1/3 of cases it is), the number of firms reporting the need for such innovations is not insignificant. It signals that companies are often pushing themselves to do something new through working on ITER and this is promising for delivering further economic benefits in future.

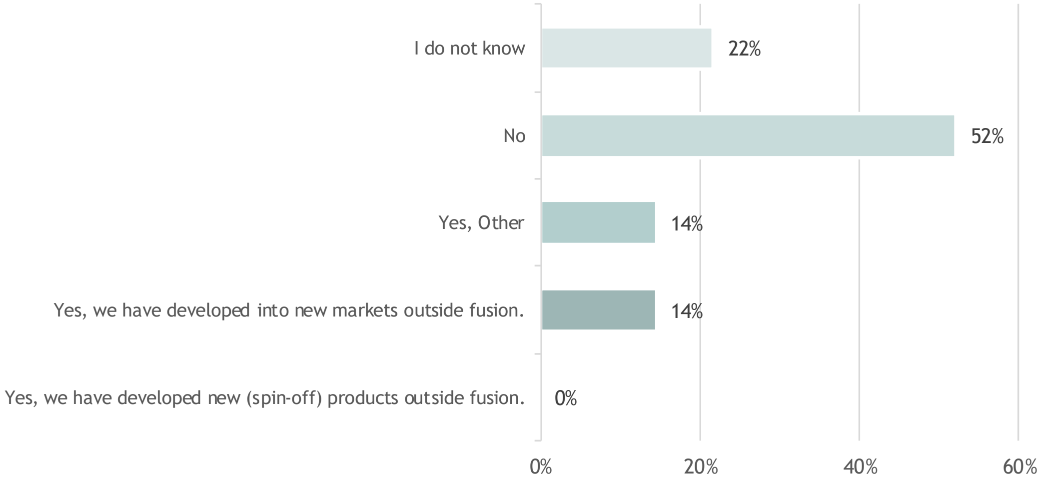
3.5. New business opportunities and (international) cooperation

So far, the implementation of the contract(s) has given rise to new business opportunities for 26% of the companies/ organisations that responded to the survey (100% minus 52% for 'no' and 22% for 'I do not know', see Figure 3-14). In half of the cases this consists of the development into new markets outside fusion, while in the other half of the cases a variety of other examples were provided. These examples include:

- "The level of specialisation in structural dynamics and seismic engineering acquired as part of the implementation of our contracts with F4E is helping us to seek new business opportunities in other markets inside and outside fusion";
- "For inside fusion, we already have several contracts with IO, whereas for outside fusion, we are still in the process of developing new business opportunities";
- "Increase portfolio services in our more consolidated Fission Market; opportunities in other research reactors; increase the international projection";
- "Industry market for Materials Treatments";
- "Increase project volume managing capacity in magnets for particle accelerators";
- "It has created new opportunities within fusion, not really outside it".

An example of a company that was able to strengthen its position in several important world markets as a result of implementing ITER contracts is presented in the textbox below. Note that the textbox is based on one of the case studies developed in the study.

Figure 3-14: Has the implementation of the contract(s) given rise to new business opportunities for your company/ organisation? (n=69)



Source: stakeholder survey

Example from case study (No.1) Bruker Biospin

Bruker Biospin is a subsidiary of Bruker Corporation, which has more than 6,000 employees at 90 locations worldwide. Bruker delivers a comprehensive range of research tools enabling life science, materials science, analytical chemistry, process control and clinical research. In 2009, Bruker was awarded a contract by F4E for the procurement of 37 tonnes of niobium-tin superconducting wires, worth EUR 24.5 million.

Nuclear fusion at ITER requires superconducting magnets able to confine the ultra-hot plasma in which the fusion processes take place. In ITER, 18 coils will shape a magnetic cage responsible for keeping the plasma away from the walls of the vessel. Europe has been tasked with the production of ten of these so-called 'Toroidal Field coils' (one of which will be kept as spare), whilst Japan will manufacture the other nine. Bruker Biospin, is responsible for producing the specific niobium-tin strands for the coils.

The experience gained at ITER has contributed to making niobium-tin the standard for high-end Nuclear Magnetic Resonance (NMR) and Magnetic Resonance Imaging (MRI) technology, and helped to make Bruker Biospin a world leader in these fields. NMR and MRI are widely applied for research and imaging in medicine, life sciences and materials analytics. The contract came about through a long-standing research cooperation between Bruker and the Karlsruhe Institute for Technology (KIT) that still continues today. This cooperation was based on the expertise that KIT acquired in the field of superconducting technology during its multi-year participation in the Euratom Fusion Energy Programme, and has generated several patents of joint ownership with Bruker.

Supplying ITER with niobium-tin superconducting strands, Bruker Biospin improved its own tin wire manufacturing process: the company had to overcome technical issues in terms of strand quality, which triggered improvements in the whole manufacturing line: yield, stability and quality. This know-how helped in increasing the yield and quality of the tin wire manufacturing process and enhanced process stability. The tin wire required for ITER procurement were of higher quality than wires normally produced by Bruker, notably in terms of external roughness.

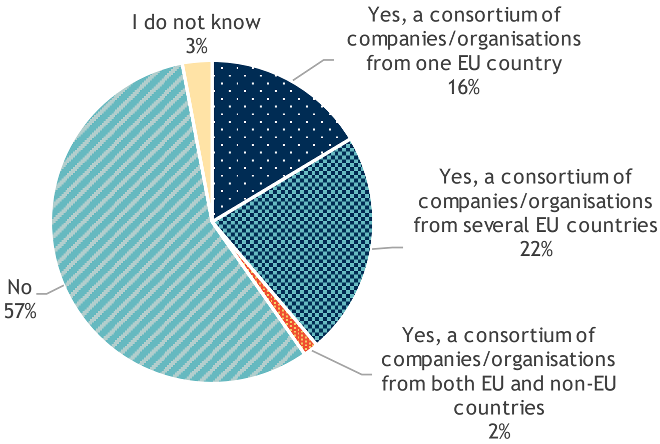
In 2016, Bruker held a share of about 10% of the global superconducting wires market, valued at US$ 638.1 Million in that year. In the same year Bruker also acquired Oxford Instruments, who held another 8.8% of this market. As a result of the ITER contract, Bruker was able to improve its knowledge on the application of superconducting strands, which contributed to its use in other analytics application fields - in particular MRI and NMR. In these markets Bruker is one of the main actors, with clients including Siemens, CERN, Philips, General Electric and Mitsubishi Electric. With a revenue of $107 million in 2016, Bruker also holds a 1.6% share of the global MRI market, which was valued at US$ 6.6 billion in 2017 (€6.1 billion), and is expected to grow at a rate of 6.6% during 2017-2022. The NMR market amounted to 0.77 billion in 2016 and is projected to reach USD 0.95 billion in 2022. With a revenue of $0.56 billion in 2016, Bruker is the world leader in this market (73% market share).

A substantial minority of the respondents (39%) have formed or entered into a consortium for implementing the contract(s), see figure 3-6. These consortia concern both national and EU-wide consortia (in more or less the same proportion), only one respondent indicated that a non-EU country was also involved in the consortium.

Out of the 26 respondents that formed/ entered into a consortium, 10 (which is 15% of 66) indicated that synergies or new opportunities have emerged outside the direct realm of the F4E contract(s) as a result of participating in this consortium. Explanations and examples of the respondents include:

- “We are exploring additional work in other areas of the nuclear market with a number of partners from the various F4E contracts we have had. Some of this work is currently being delivered in the Nuclear New Build market, and some in Decommissioning”;
- “Development and manufacture of sensors for our own devices”;
- “New opportunities regarding design and manufacturing”;
- “Possibility to carry out new, common projects related to fusion diagnostics”;
- “We have had other opportunities in the design of buildings”;
- “New consortium for another F4E contract”;
- “Collaboration with industry and other Research Associations have strengthened existing partnerships to better answer call for tenders in fusion related field”.

Figure 3-15: Did you form or enter into a consortium for implementing the F4E contract(s)? (n=67)



Source: stakeholder survey

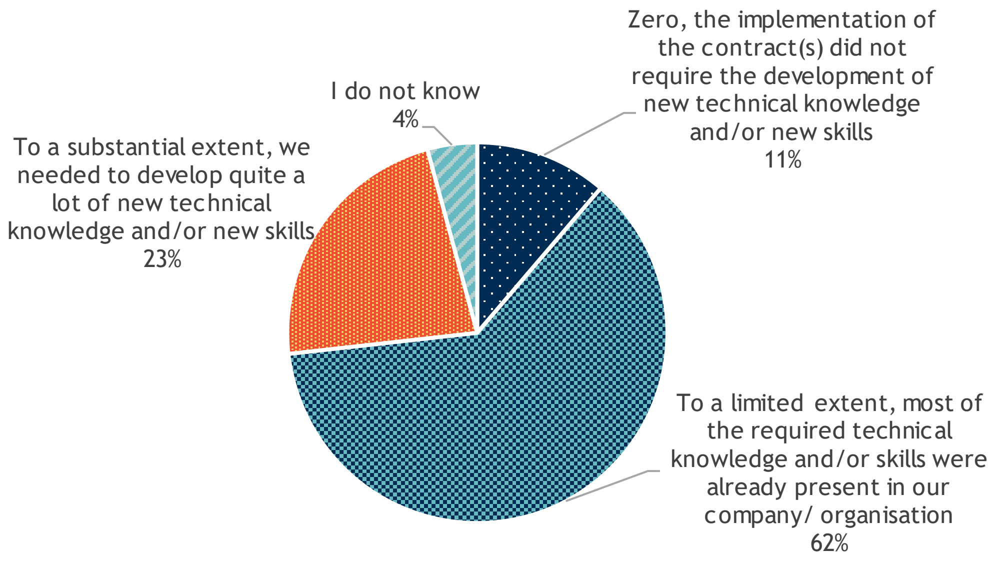
In addition, 25% of the respondents (17 out of 67) reported the presence (or anticipation) of any other effects (other than already mentioned in the survey) resulting from the implementation of the contract(s). Almost half of the examples given concern the increased likelihood of being involved in the future development of fusion/ ITER. One of these examples included enhanced participation in other Big Science projects, while another example referred to potentially more fusion related work for the private sector. Other examples in this context include:

- “The fusion work has resulted in us setting up a dedicated part of the business to pursue related work. It has also helped the integration of parts of our international business, pulling remote offices closer together”;
- “All effects related to design, building materials and structural engineering”;
- “High heat flux testing for components other than for their usage in fusion”;
- “International expansion; networking with other high technological value companies; becoming more attractive for highly skilled personnel”;
- “Competency growth that will allow to develop new offers and markets”;
- “Improved skills and the capability to execute engineering analysis on very complex systems.”
- “We could tender with F4E references.”

3.6. Knowledge and skills development

Reflecting on the development of new knowledge or skills as a results of implementing F4E contracts on ITER 85% of the respondents indicated that the implementation of the ITER contract(s) resulted in acquiring new knowledge and/or the development of new skills, either to a limited extent (62%) or to a substantial extent (23%), see Figure 3-16.

Figure 3-16: To what extent has the implementation of the F4E contract(s) resulted in your company/ organisation acquiring new knowledge and/or developing new skills? (n=71)



Source: stakeholder survey

Out of the 60 respondents that provided these answers, 48 indicated on a drop-down list the main technological field(s) in which new knowledge was acquired and/or new skills developed. The top-ten technological fields are presented in Table 3-10. The five fields most often mentioned are engineering processes, all engineering and design activities, mechanical design (all three mentioned by 29% of the respondents), non-destructive tests and welding techniques (both 21%). Technological fields that were less often mentioned and are not included in the table include remote handling systems, destructive tests and characterisation, machining of large scale components, superconductivity and superconductor magnets (all 10%), power electronics and high precision machining (both 8%).

Table 3-10: Can you indicate the field in which new knowledge had to be acquired and/or new skills had to be developed? (n=48)

	Technology field	Percentage of respondents
1.	Engineering processes	29%
2.	All engineering and design activities	29%
3.	Mechanical design	29%
4.	Non-destructive tests	21%
5.	Welding techniques	21%
6.	Technologies of fabrication	19%
7.	Nuclear engineering	17%
8.	Electromagnetic analysis	17%
9.	Standard manufacturing and joining processes	15%
10.	Materials	15%

Note: N is the number of unique respondents; multiple answers were possible
Source: stakeholder survey

4. Cross cutting analysis

Key findings

- Spending on ITER by F4E is expected to have significant positive economic impacts compared to no spending, with 72 400 job years to be created; and almost €15.9 billion in gross value added (GVA) to be generated between 2018 and 2030;
- Benefits increase further from spin-offs, indicative modelling results suggest that these further increase the gross impacts by around 15%, but more importantly in terms of net impacts leading to a near doubling (+€449 million) of GVA and turning net job year decline into an increase of 2 300 job years (+24%) between 2018-2030;
- Existing scenarios suggest that by 2050 there will still be a need for a large-scale, low carbon energy source such as fusion power, and that fusion can bring important benefits in reducing EU energy dependence to give an advantage compared to some other technologies;
- Whilst public (EU) funding of fusion energy is significant in comparison to the total EU energy research funding it is also the case that other technologies benefit from significant national and private sector funding and support which fusion energy does not receive to anywhere near the same extent;
- In comparison to other large infrastructure Big Science projects (CERN, ESA), ITER is performing well:
    - Despite still being in its construction phase, its cost is almost completely recovered in GVA at the current rate (93%) – other comparable projects only managed to achieve breakeven a few years into their operational phase;
    - ITER's employment multiplier is currently almost 50% higher than that of comparable Big Science projects – however, this could be precisely due to the fact that it is still in its construction phase;
    - Given the pathway of the assessed projects at CERN and ESA, it seems likely that ITER is also set for a development that will provide a long-term return on investment (post-2025).
- There is ample opportunity for industry to benefit from synergies across Big Science projects. Securing a contract on one Big Science project can facilitate entrance into work for another;
- In order to foster the benefits from ITER persisting beyond its construction phase, experience from CERN and ESA suggests that the first steps for building a sophisticated technology transfer architecture need to be taken as soon as possible.

This chapter discusses ITER spin-offs in a wider societal perspective. First, possible economic impacts of ITER in terms of employment are modelled with two possible future scenarios (section 4.1). Then, the energy context of ITER is discussed (section 4.2). Finally, ITER is compared to other big science projects (section 4.3).

4.1. Aggregate economic impacts from econometric analysis

The potential mid-term (up to 2030) employment effects of ITER-related investments were assessed using the E3ME model. This analysis was based on forecasts on the size and sector distribution of future contracts carried out in earlier tasks of the project. The gross and net impacts of future ITER contracts were assessed by comparing each scenario to the standard E3ME baseline scenario. This baseline is calibrated to match a set of projections that are published by the European Commission and the International Energy Agency. For a more detailed description of the scenarios and modelling methodology please see Annex D.

As in the historical analysis in chapter 3, two scenarios were analysed in this assessment: (1) a gross impact scenario, in which we assume that future ITER investment is purely additional investment (compared to the baseline); and, (2) a net impact scenario where we assume that the investment money spent on ITER activities would instead have been spent on alternative investments, in order to assess the added benefit of the programme.

In summary, the gross impact results presented in the sections below show positive outcomes for employment and GVA. A greater number of jobs are created in the earlier years of the time period, trailing off towards 2030, reflecting the timing of the investment. In total, 72,400 job years are created between 2017 and 2030, mainly in business services and industry sectors. The gross GVA impacts are also positive, although the largest impacts occur mid-way through the period, coinciding with the most intensive investments. In total, an additional €15.9bn of GVA may be generated.

The net impacts on GVA are positive throughout the period. When compared to an alternative investment programme, the net benefit of ITER investment is an additional €454m in GVA. The positive impacts on GVA are lower at the start of the period, due to higher levels of investment in low value-added sectors such as construction and specialised industry than is likely from an alternative investment programme. Later in the period, when investment in business services and non-business services sectors becomes more prominent in the ITER investment programme, the results show higher levels of GVA. The net impact on employment shows some evidence of a lag in the effect compared to the GVA results as it typically takes time for labour markets to adapt to changes in production levels. In some years there are small negative (<-350) impacts of investing in ITER rather than an alternative programme, but in 2030 an additional 400 jobs are created. The cumulative impact over the period 2018-2030 is -1,100 fewer jobs created by the ITER programme compared to an alternative investment programme. However, the difference in the number of jobs created each year is very small (<+/-350), meaning it can be reasonably concluded that the effects of both investment programmes are approximately the same over this period.

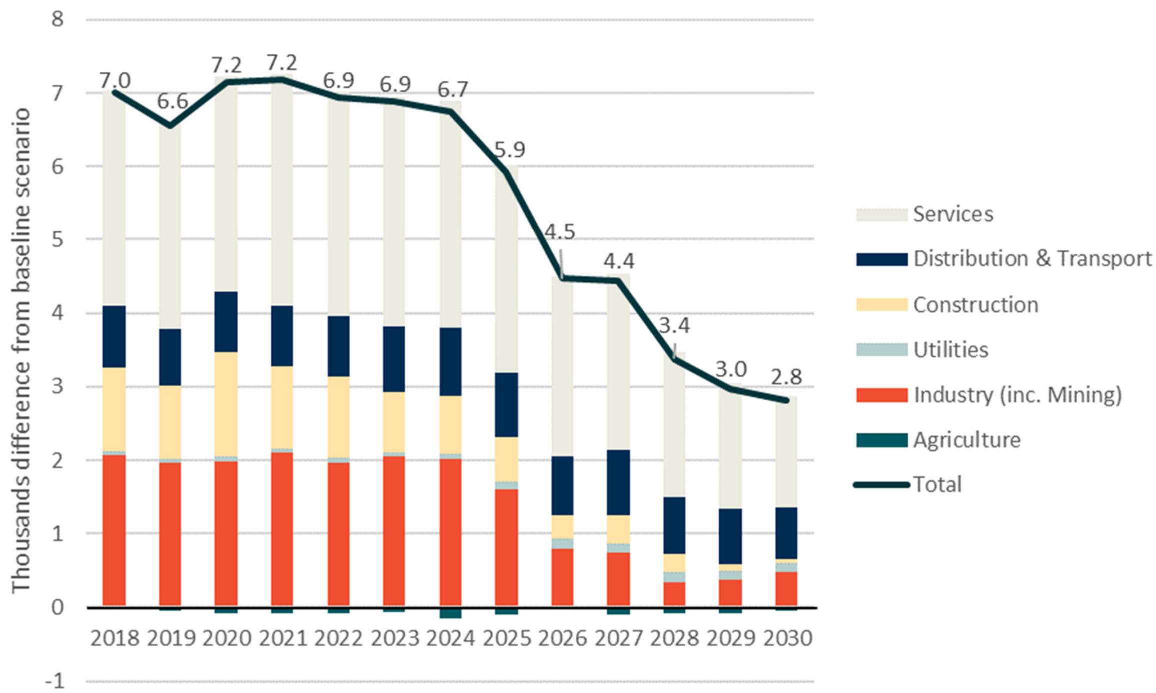
4.1.1. Employment

Gross impact scenario

We begin by considering the gross employment impact of future investment surrounding ITER activities. Figure 4-1 and Figure 4-2 below show employment results for the EU28 as a whole under this scenario. The impact on employment is small (<0.01% of total EU28 employment), so the results are presented as absolute differences from the baseline.

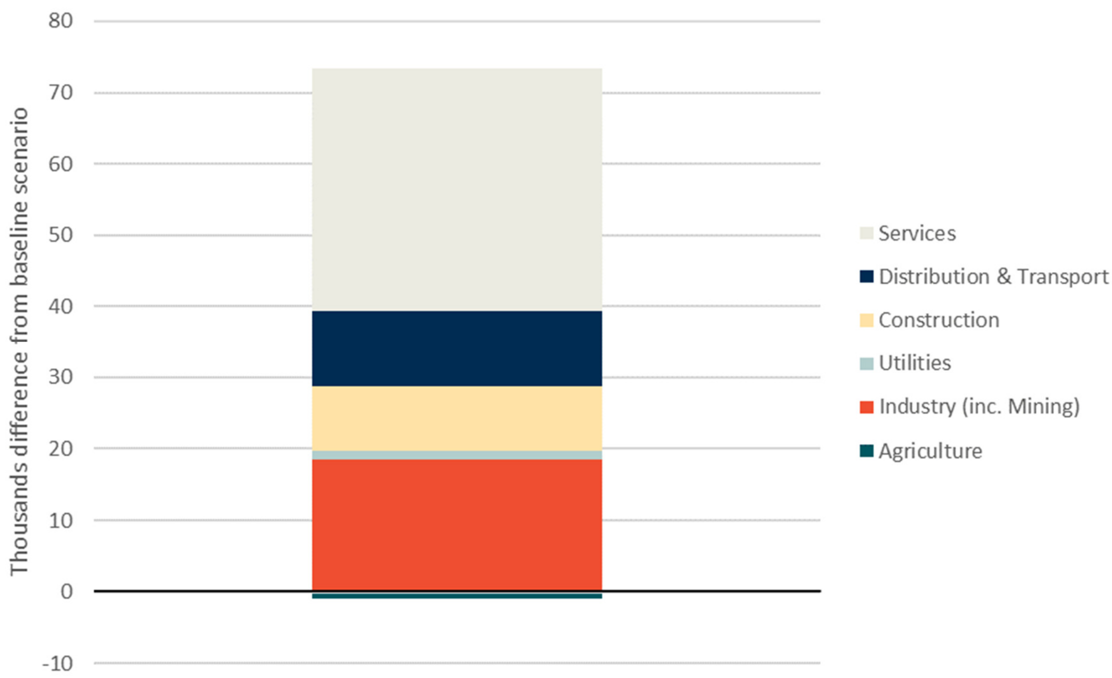
The model results show that future ITER-related investments have a positive impact on employment figures, with approximately 7,000 jobs created in 2018, gradually declining to 2,800 additional jobs by 2030. The time profile correlates to the timing of the investment within the ITER programme, i.e. it is relatively front-loaded in the projection period. In total, over the period 2018-2030 around 72,400 additional job years are created (see Figure 4-2).

Figure 4-1: Total EU28 impact on employment of the ITER programme, 000's difference from baseline



Sources: E3ME, Cambridge Econometrics.

Figure 4-2: Cumulative total EU28 impact on employment of the ITER programme, 000's difference from baseline



Sources: E3ME, Cambridge Econometrics.

The largest employment impacts are in business services and industry. There are around 2,200 additional jobs in the business services sector in 2018, falling to 800 by 2030. These jobs result mainly from the indirect and induced effects from higher income expenditure (see also Table 4-2), as well as some direct investment in this sector. 2,100 jobs are created in the industrial sector in 2018, falling to 500 by 2030. As in the historical analysis, the sector includes both basic manufacturing that features in the supply chain for the construction sector (so mainly indirect jobs) and the more advanced components that are needed directly for ITER itself. Construction and non-business services also continue to receive large shares of the overall investment in this period, leading to the creation of around 900 job years in each of these sectors in total.

One sector (agriculture) has a small negative impact due to wage effects. This means that as total employment increases, average wage rates are pushed up, which could result in lower employment levels in sectors that are not linked to ITER investment but which are sensitive to changes in the average price of labour.

At Member State level, the largest impacts are in Germany (+11 700), France (+13 000) and Spain (+20 300), and these are concentrated in the first half of the period. The timing of these impacts is due to the intensity of the construction and development phase of the ITER facility, which will continue until construction is expected to reach first plasma in 2025. Full country level results are provided in Annex F.

It can also be noted from Table 4-2 that indirect + induced job years in 2030 represent approximately 1,900 of the 2,800 job years created. **This ratio means that for every direct job year created by ITER approximately 2.1 job years are indirectly created or induced.** This ratio remains quite constant over time.

Table 4-1: Total EU28 impact on employment of the ITER programme, 000's difference from baseline

Sector	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	Total job years
Agriculture	0.0	0.0	-0.1	-0.1	-0.1	-0.1	-0.2	-0.1	0.0	-0.1	-0.1	-0.1	-0.1	-1.0
Industry (inc. Mining)	2.1	2.0	2.0	2.1	2.0	2.0	2.0	1.6	0.8	0.7	0.3	0.4	0.5	18.5
Utilities	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	1.2
Construction	1.1	1.0	1.4	1.1	1.1	0.8	0.8	0.6	0.3	0.4	0.3	0.1	0.1	9.1
Distribution & Transport	0.8	0.8	0.8	0.8	0.8	0.9	0.9	0.9	0.8	0.9	0.8	0.7	0.7	10.7
Services	2.9	2.8	2.9	3.2	3.1	3.1	3.1	2.8	2.4	2.4	2.0	1.7	1.5	34.0
Total	**7.0**	**6.6**	**7.2**	**7.2**	**6.9**	**6.9**	**6.7**	**5.9**	**4.5**	**4.4**	**3.4**	**3.0**	**2.8**	**72.4**

Sources: E3ME, Cambridge Econometrics.

Table 4-2 Direct and indirect/induced employment impacts from ITER programme, 000s difference from baseline, 2030

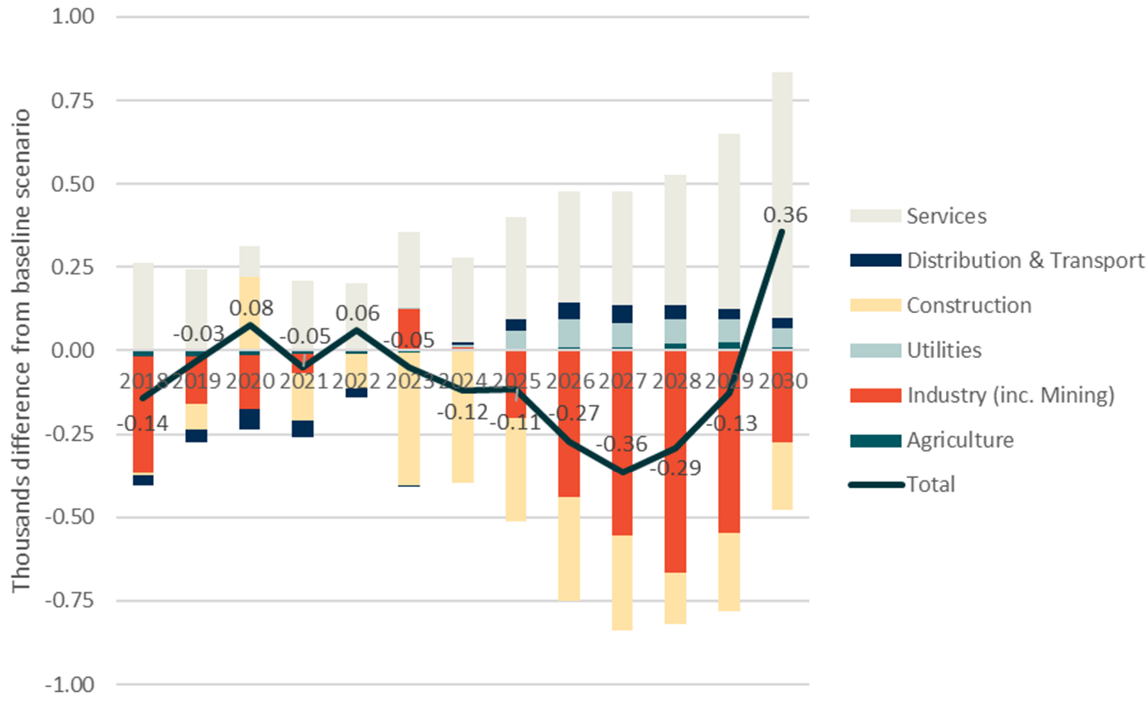
Sector	Direct	Indirect + Induced
Agriculture	0.0	-0.1
Industry (inc. Mining)	0.2	0.3
Utilities	0.1	0.1
Construction	0.0	0.1
Distribution & Transport	0.0	0.7
Services	0.7	0.8
Total	**0.9**	**1.9**

Sources: E3ME, Cambridge Econometrics.

Net impact scenario

Next, we consider the net employment impact of investment surrounding ITER activities. Under this scenario we compare the effect of ITER activities to a similar amount of spending (at Member State level) on alternative investments (see Annex D for a more detailed scenario description). Figure 4-3 and Figure 4-4 below show employment results for the EU28 as a whole under this scenario.

Figure 4-3: EU28 impact of the ITER programme (rather than alternative investment) on employment, 000s difference from baseline

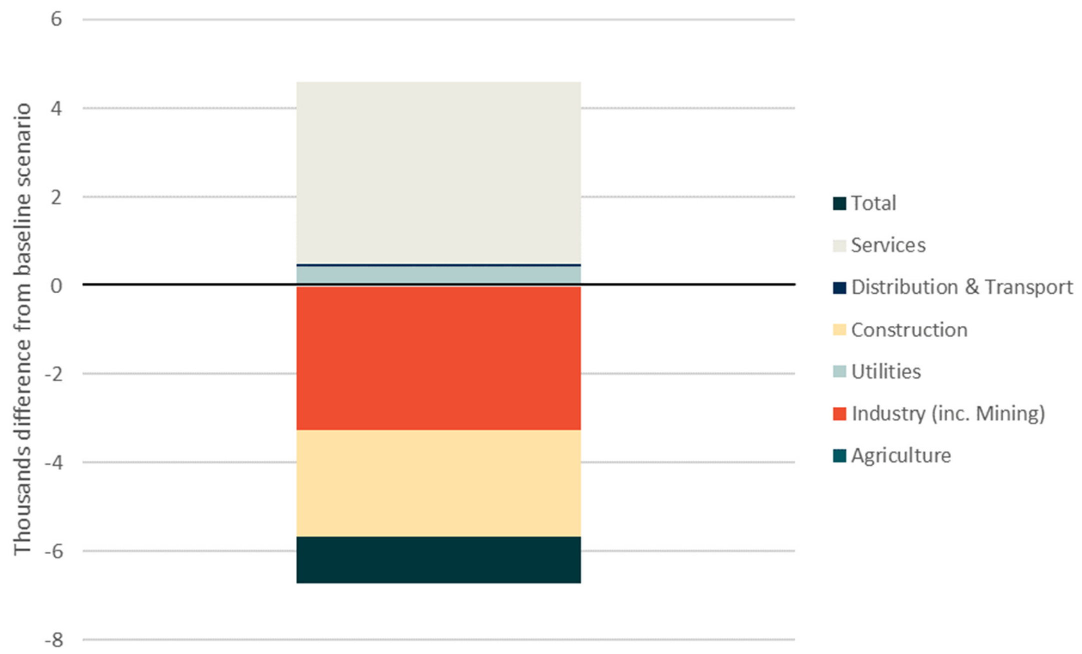


Sources: E3ME, Cambridge Econometrics.

The effects on total employment of spending on ITER rather than other economic activities is somewhat ambiguous, with rather small impacts each year. Over much of the period the alternative investment creates more job years (represented by negative numbers in the table) but in 2030 the number of job years created by the F4E ITER spending is greater than the alternative investment programme. In the first half of the period the F4E ITER spending invests more in non-business services compared to the alternative investment programme, leading to more jobs in this sector, but less in construction, industry and labour-intensive service sectors, creating fewer jobs in those sectors.

Whilst the alternative investment programme creates marginally more direct jobs in total, there are greater differences in the indirect jobs this programme generates. This is due to the sectoral allocation of the investment funds, and the greater proportion that is invested in sectors with longer supply-chains or sectors that generate increased induced consumption. Furthermore, investment is spread between a wider variety of sectors within manufacturing and business services, creating greater indirect effects. In total there is a small negative impact on job years (-1,100) over the 2018-2030 period compared to the alternative investment (see Figure 4-4). However, the impacts of potential spin-offs are not taken in to account within the model results. Additional analysis presented at the end of this section implies that a further 2,300 jobs could be created as a result of spin-offs over this time period, leading to a positive outcome overall.

Figure 4-4: Cumulative EU28 impact of the ITER programme (rather than alternative investment) on employment, 000s difference from baseline



Sources: E3ME, Cambridge Econometrics.

The impacts at Member State level are also driven by the relative labour intensities of the sectors impacted in each country. The largest positive effects are in Spain (+6 500 job years), as around 50% of ITER-related investment is targeted towards labour-intensive business and non-business service sectors, whilst the largest negative effects are in France (-7 000 job years), as most of the ITER-related investment here is targeted towards specialised industry and construction, and less towards labour-intensive service sectors. Full country level impacts are presented in Annex F.

Table 4-4 shows that in 2030 ITER creates roughly the same number of direct jobs and indirect+induced job years compared to the alternative investment. The total impact on employment is largely determined by the relative labour intensities and costs of the different sectors; negative numbers in the table can be explained by the high shares of labour used in some of the sectors affected. The indirect effects on business services (another labour-intensive sector) tend to follow the more aggregate results for employment.

Table 4-3: EU28 impact of the ITER programme (rather than alternative investment), 000s difference from baseline

Sector	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	Total job years
Agriculture	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Industry (inc. Mining)	-0.3	-0.1	-0.2	-0.1	0.0	0.1	0.0	-0.2	-0.4	-0.6	-0.7	-0.5	-0.3	-3.3
Utilities	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.1	0.1	0.1	0.1	0.4
Construction	0.0	-0.1	0.2	-0.1	-0.1	-0.4	-0.4	-0.3	-0.3	-0.3	-0.2	-0.2	-0.2	-2.4
Distribution & Transport	0.0	0.0	-0.1	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.0	0.0	0.0	0.0
Services	0.3	0.2	0.1	0.2	0.2	0.2	0.3	0.3	0.3	0.3	0.4	0.5	0.7	4.1
Total	**-0.1**	**0.0**	**0.1**	**0.0**	**0.1**	**-0.1**	**-0.1**	**-0.1**	**-0.3**	**-0.4**	**-0.3**	**-0.1**	**0.4**	**-1.1**

Sources: E3ME, Cambridge Econometrics.

Table 4-4: Direct and indirect/induced employment impacts from ITER programme (compared to alternative investment), 000s difference from baseline, 2030

Sector	Direct	Indirect + Induced
Agriculture	0.0	0.0
Industry (inc. Mining)	-0.2	-0.1
Utilities	0.0	0.0
Construction	-0.2	0.0
Distribution & Transport	0.0	0.0
Services	0.6	0.1
Total	0.2	0.1

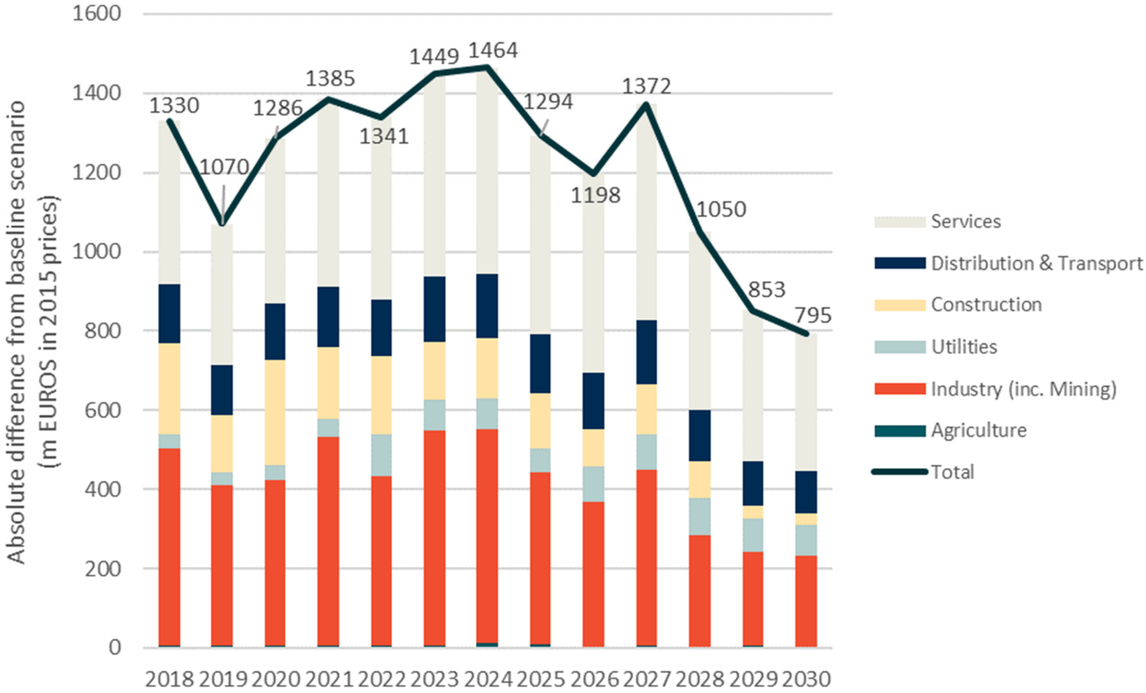
Sources: E3ME, Cambridge Econometrics.

4.1.2. Growth

Gross impact scenario

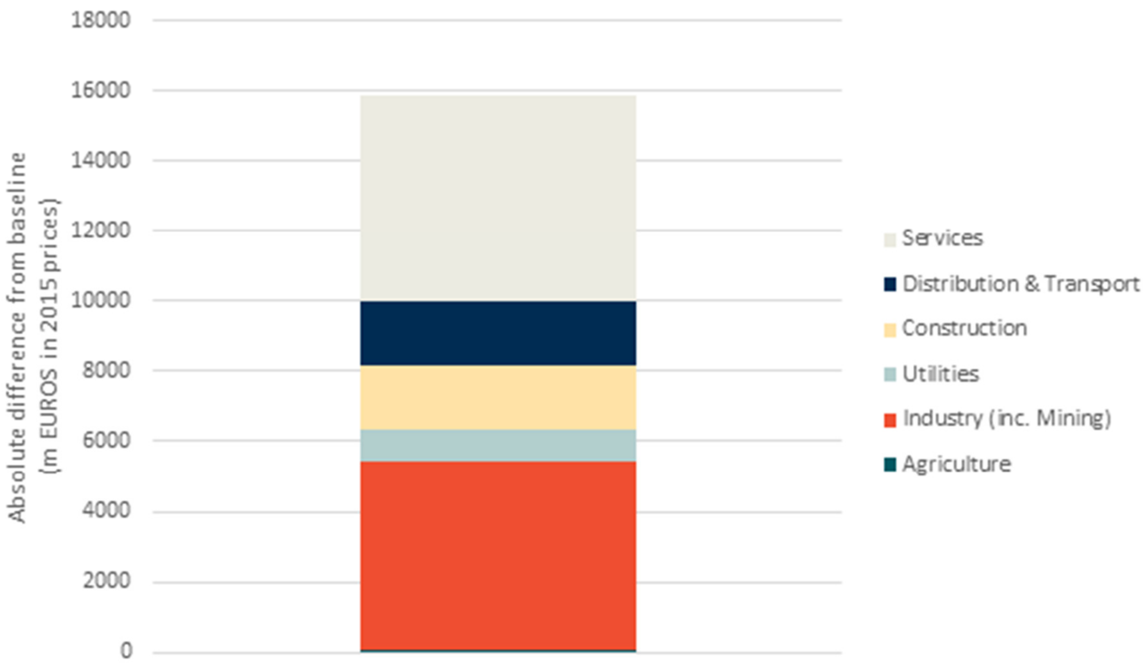
Figure 4-5 and Table 4-5 show the impact on GVA up to 2030, compared to baseline. There is a pattern for higher impacts in the middle of the projection period, tailing off up to 2030. The model results show that the highest increase in GVA is in 2024. The total GVA impact over this period is estimated at €15.9 billion (see Figure 4-6), this compares to the expected F4E spending of €13.6 billion over the same period, representing a small positive multiplier of 1.2 for every euro spent.

Figure 4-5: EU28 impact of the ITER programme on GVA, absolute difference from baseline (m 2015 €)



Sources: E3ME, Cambridge Econometrics.

Figure 4-6: Cumulative EU28 impact of the ITER programme on GVA, absolute difference from baseline (m 2015 €)



Sources: E3ME, Cambridge Econometrics.

The largest growth impacts are in industry and business services and there are also large increases in GVA in construction and non-business services. As with the results for employment, most of the additional construction activity can be considered a direct impact, while most of the additional activity in business services is indirect/induced (see Table 4-6). Within industry there is a combination of direct effects (producing equipment for ITER) and indirect effects (mostly supplying the construction sector). The split between direct (€251m) and indirect+induced (€544m) impacts in 2030 reflects a ratio of €2.17 of indirect and induced GVA for every euro GVA created directly.

The spread of benefits across Member States is very similar to the historical analysis. In general there is quite a close link between the size of the increase in GVA and the overall size of each country's economy. France (+€5 917m), Spain (+€2 123m), and Germany (+€2 052m) are the main beneficiaries in terms of GVA, since these are the countries in which the highest shares of ITER investment are expected to occur over this period. Full country level results are presented in Annex F.

Table 4-5: EU28 impact of the ITER programme on GVA, absolute difference from baseline (m 2015 €)

Sector	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	Total cumulated
Agriculture	6	5	7	7	7	7	13	9	0	7	3	6	4	80
Industry (inc. Mining)	498	404	415	525	425	543	538	433	367	441	282	237	229	5337
Utilities	36	34	39	46	109	76	78	62	90	91	93	82	78	914
Construction	230	144	265	180	196	147	153	140	93	126	94	33	26	1829
Distribution & Transport	148	125	143	154	143	162	162	149	143	163	129	113	107	1841
Services	412	357	417	473	462	513	520	501	504	545	448	382	351	5886
Total	**1330**	**1070**	**12863**	**1385**	**1341**	**1449**	**1464**	**1294**	**1198**	**1372**	**1050**	**853**	**795**	**15887**

Sources: E3ME, Cambridge Econometrics.
Notes: The cumulated figures are in real terms but not further discounted.

Table 4-6: Direct and indirect/induced GVA impacts from ITER programme, m 2015 €, difference from baseline, 2030

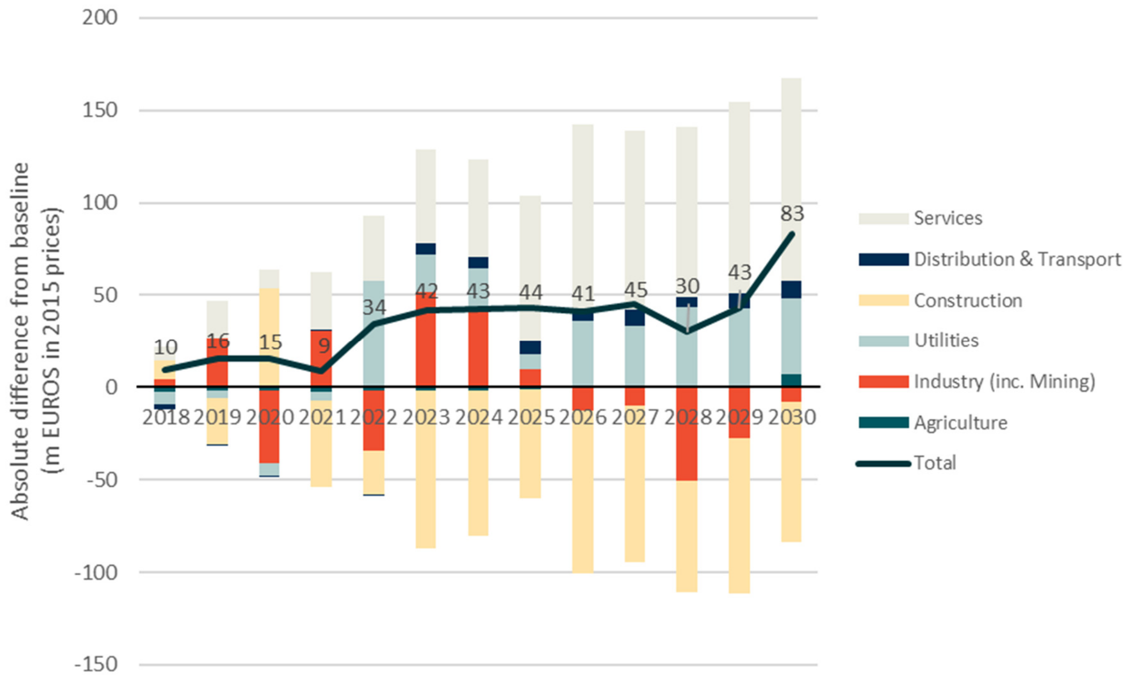
Sector	Direct	Indirect + Induced
Agriculture	0	4
Industry (inc. Mining)	102	127
Utilities	39	39
Construction	0	26
Distribution & Transport	1	106
Services	109	242
Total	**251**	**544**

Sources: E3ME, Cambridge Econometrics.

Net impact scenario

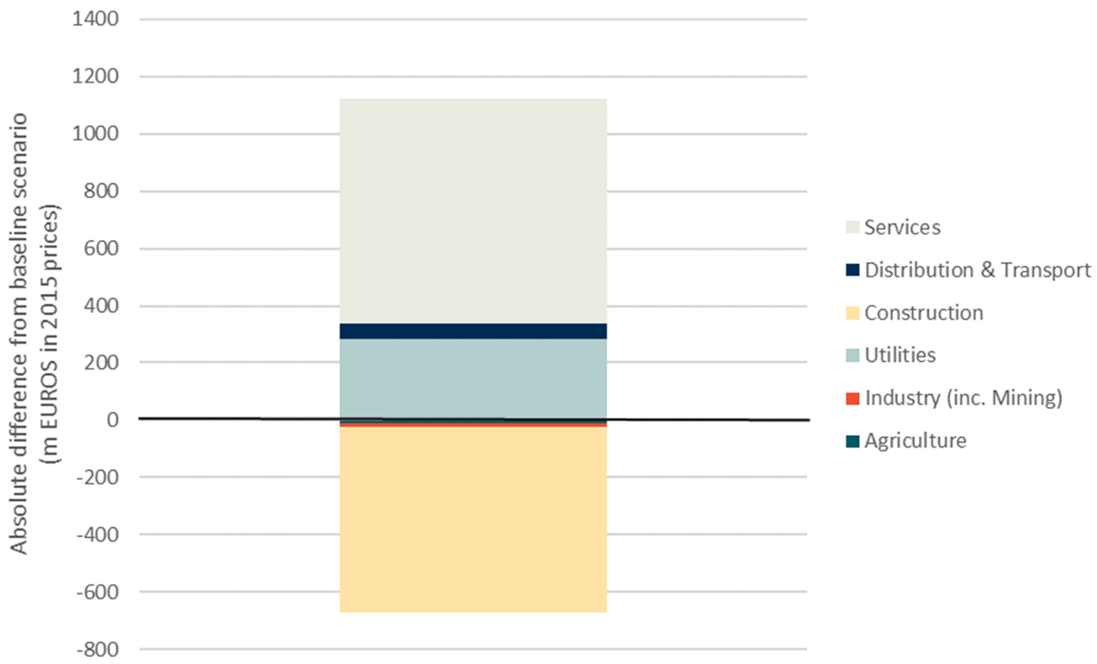
Figure 4-7 and Table 4-7 show the impacts of the ITER programme on GVA up to 2030, compared to an alternative investment programme. The table shows that the overall differences are small, between €10m and €83m additional GVA is generated by the ITER investment programme each year. Over the 2018-2030 period the cumulative impact is estimated at €454 million, compared to the alternative investment programme. The model results do not capture the additional impact of potential technological spin-offs or new business opportunities that may arise as a result of ITER-related activities. The overall growth impact of the ITER investment programme could be higher if the additional GVA attributed to spill-overs and the subsequent investment this may generate is taken in to account, this potential is discussed later in this section.

Figure 4-7: EU28 impact of ITER (rather than alternative investment) on GVA, absolute difference from baseline (m 2015 €)



Sources: E3ME, Cambridge Econometrics

Figure 4-8: Cumulative EU28 impact of ITER (rather than alternative investment) on GVA, absolute difference from baseline (m 2015 €)



Sources: E3ME, Cambridge Econometrics

Once again, at sectoral level there are bigger differences. The ITER programme requires higher levels of construction and industry in the first half of the period than is likely from alternative investment (positive numbers in the figure/table). This leads to lower levels of additional GVA at the start of the 2018-2030 period, as these sectors use a high proportion of intermediate outputs, and therefore have lower levels of value-added. Later in the period, when investment in business services and non-business services sectors becomes more prominent in the ITER investment programme, the results show higher levels of GVA.

At Member State level there are a few notable impacts, with GVA increasing overall in some Member States, while in others GVA is lower than in the alternative investment case. GVA is higher in Spain when investment is spent on the ITER programme, due to the high proportion of investment in business and non-business services under this programme (partly because F4E is located in Barcelona). Conversely, France has a lower level of GVA. France's result can be explained by its high share of investment targeted at specialised industry and its relatively low share of industrial production, which means that many of the indirect effects are lost because components are imported rather than produced domestically.

Table 4-8 shows a breakdown of direct and indirect/induced effects. The indirect and induced impacts are higher than the direct impacts because of the differences in supply chains in the two investment programmes. In 2030 the direct impact on GVA is €26.4m and the indirect+induced impact is €56.8m, representing a multiplier of almost 2.15 on the direct impact, i.e. that **for every euro spent on ITER in 2030 a further €2.15 is indirectly generated or induced.**

Table 4-7: EU28 impact of ITER (rather than alternative investment) on GVA, absolute difference from baseline (m 2015 €)

Sector	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	Total cumulated
Agriculture	-3	-2	-2	-2	-2	-2	-2	-1	-1	0	0	0	7	-10
Industry (inc. Mining)	4	27	-39	30	-32	52	41	10	-12	-10	-50	-27	-8	-14
Utilities	-6	-4	-7	-5	58	21	23	9	36	33	44	42	42	284
Construction	10	-25	54	-47	-24	-85	-79	-59	-88	-84	-60	-84	-76	-646
Distribution & Transport	-3	0	0	1	-1	6	6	7	7	9	5	9	9	53
Services	7	20	10	32	35	51	53	79	99	97	92	103	110	787
Total	**10**	**16**	**15**	**9**	**34**	**42**	**43**	**44**	**41**	**45**	**30**	**43**	**83**	**454**

Sources: E3ME, Cambridge Econometrics.
Notes: The cumulated figures are in real terms but not further discounted.

Table 4-8: Direct and indirect/induced GVA impacts from ITER programme (compared to alternative investment), m 2015 €, difference from baseline, 2030

Sector	Direct	Indirect + Induced
Agriculture	-1	8
Industry (inc. Mining)	-6	-3
Utilities	36	6
Construction	-78	2
Distribution & Transport	0	9
Services	76	34
Total	**26**	**57**

Sources: E3ME, Cambridge Econometrics.

Additional impact of spin-offs

As discussed within the ex-post results, and following on from the earlier sections, future ITER contracts are likely to lead to further technological spin-offs and new business opportunities. These spin-offs may improve productivity and subsequently lower costs within certain sectors, or new markets may develop. Using the approach mentioned previously in Section 3.2.2 and described in more detail in Annex D, we have made some simple assumptions that allow us to determine the specific additional impacts of spin-offs on employment and growth between 2018 and 2030.

The gross impact results show that spin-offs may generate an extra 10,900 jobs between 2018 and 2030 and an increase in GVA of €2,248m over this period. In order to consider the net benefit of spin-offs from the ITER investment programme, we compare this to the spin-off impacts of an alternative investment programme. ITER investment is found to generate an additional 2,300 job years and €449m in GVA between 2008 and 2017. The case study example below is indicative of these types of benefits and the multipliers that can be achieved.

Case study example (No.9) VTT - economic benefits from spin-offs

VTT noted that by undertaking contracts for F4E it has been able to gain many more contacts in industry, and these are proving useful for exploiting new synergies and exploring new business opportunities across VTT as a whole, not just in the area of fusion. Specific opportunities were identified in the areas of nuclear decommissioning, mining and the space industry.

VTT has found that most of its main technological developments and spin-offs tend to emerge from cooperation with universities. The process often involves the cooperation with universities in discovering or developing a particular technology or material and then to turn this into an application in the fusion sector and beyond. Examples of such technologies already developed through work on ITER and their further applications include:

- A tool for the design of complex systems;
- Augmented and virtual reality tools – also used in the space industry;
- A new technology for cleaning dust from irradiated products – also used for surface treatment in metal industry, electronics, apart from nuclear);
- Sensor technologies (via F4E diagnostics contracts).

The latter two developments have been particularly successful, with the economic returns in the non-fusion sectors already surpassing the returns in the fusion sector. It was not possible to quantify these effects exactly, but a Principal Scientist at VTT felt that returns x2-3 bigger than the initial investment are being made, which compares favourably with other sectors in which VTT works.

4.2. In the context of the EU energy system

4.2.1. In the context of EU energy needs and supply

Current European energy and climate policy objectives have a time horizon of 2050. By that time, the whole European energy system should be 80 to 95% decarbonised. In the context of this research project on ITER, several interviews were carried out with energy policy and technology specialists. In addition, a literature review was carried out on the expected contribution of ITER and its successor DEMO to the 2050 energy targets.

The main conclusion of this analysis is that it is not realistic to expect any substantial contribution of ITER and DEMO to the 2050 European energy and climate targets. For that purpose, both ITER and DEMO are simply too small. With an intended size of 500 MW and 2-4 GW respectively, the plants would contribute 0.05% and 0.2 to 0.4% to the already installed 1,000 GW of electricity generation capacity in Europe[24]. Up to 2050, ITER should therefore be largely seen as a project comparable to CERN, ISS, space research and other ongoing Big Science research. The contribution of nuclear fusion to the energy system on a commercial and large-scale basis should only be regarded in a post-2050 context.

While the decarbonisation of the European energy system will be largely completed by 2050 if the European energy targets are met, this does not mean that nuclear fusion is simply a matter of 'too little, too late', as one interviewee remarked[25]. Rather, in a post-2050 situation nuclear fusion could still provide a valuable additional source in the total portfolio of low-carbon energy sources available and could also contribute to security of energy supply. Several interviewees mentioned that, as with current base-load capacity (coal, nuclear fission), in the future, fusion energy could help to balance the electricity system due to its characteristics which are complementary to intermittent electricity sources like solar PV and wind energy. An important precondition for that would be not only its capacity to compete in the low-carbon electricity market with other energy sources with similar baseload characteristics (e.g. nuclear fission), but also its public acceptance - which has proven to be a large hurdle for many energy sources over time. In that respect, some interviewees see fusion in the future substituting fission power, with one of them mentioning that 'fusion could possibly supply up to 20 or 30% of total energy demand in the future'[26].

One area of impact that could also be important to fusion energy is energy security and energy import dependence. The EU currently imports more than half of all the energy it consumes. Its import dependency is particularly high for crude oil (more than 90%) and natural gas (66%). The total import bill is more than €1 billion per day. Many countries are also heavily reliant on a single supplier, including some that rely entirely on Russia for their natural gas. This import dependence is expected to increase to 2050 in the EU reference energy scenario (from 53% in 2010 to 58% in 2050)[27]. Therefore with the likelihood that transport and heating become increasingly electrified at the same time as EU primary energy production declines, there is potentially a useful role for nuclear fusion post-2050 as a large-scale producer of electricity helping to address energy security and import dependency concerns. Therefore, fusion could be particularly useful in supplying heavy industry with electricity, as a reliable electricity and heat supply for this sector in the future will remain difficult.

It is difficult to estimate the exact size of the contribution of fusion to the post-2050 low-carbon European electricity market. However, an interesting comparison of the development of fusion energy with that of solar PV can be made, based on an article by nuclear fusion professor Niek Lopes Cardozo[28]. It states that although the photovoltaic effect was discovered as far back as 1839, solar PV started its lifetime in the 1950s, and came into the market in the 2000s, when Germany bought

[24] Entso-E (2015) Electricity generation in Europe
[25] ITER review interview, January 2018
[26] ITER impact assessment interviews, February/March 2018
[27] EC (2016) EU Reference Scenario, Brussels
[28] Lopes Cardozo, N (2014) The cradle of new energy technologies. Why we have solar cells but not yet nuclear fusion, in: Gert Jan Kramer and Bram Vermeer (eds.). The colours of energy: Essays on the future of our energy system,

wholesale into the technology. Fusion energy in Cardozo's opinion might reach maturity around 2060-2070, some 40 years later than photovoltaics, but to some extent in a similar timeframe as the fusion effect was only discovered in the 1920s. It is calculated in the article that to reach that stage a US$1,000-2,000 billion (€700-1,400 billion) upfront investment would be needed, similar to that for solar PV. However, the main difference between fusion and solar PV is that for the former a series of single big steps are needed, while the latter has been developed in a large number of smaller incremental steps, with much lower investment risks – which might partly explain the time lag that fusion power has experienced in comparison to solar PV. There is an argument therefore that, for a more rapid mature contribution of fusion to the European energy system, a larger consecutive number of demonstration projects with a smaller size than currently foreseen might be beneficial. While ITER and DEMO are already consecutive steps in the development of fusion technology, it is argued that with more and smaller experiments a faster cycle in practice could be realised. This is also in line with the needs expressed by one interviewee of a 'sufficiently modular design' of fusion power[29], yet there remain significant technical hurdles to the feasibility of a smaller design.

4.2.2. ITER funding in context

With regard to the overall **2014-2020 Multiannual Financial Framework** funding, ITER spending is allocated under the Smart and Inclusive Growth heading and more specifically under the Competitiveness for growth sub-heading.[30] The total available funds for the 2014-2020 Multiannual Financial Framework are EUR 1.1 trillion. For the 2014-2020 financial envelope the commitments foreseen by the European Budget for the ITER project amount to EUR 3.3 billion in 2008 prices. This represents 0.3% of the total funds available at the 2014-2020 Multiannual Financial Framework.[31] In the 2016 budget, the commitments for ITER amounted to EUR 330 million or 0.2% of the total 2016 EU budget.[32] Due to the nature of the financing process however the actual payments allocated reached EUR 475 million of the total 2016 EU budget.[33] In 2017, the levels of spending remained stable and even though the foreseen commitments were EUR 323 million or 0.2% of the total EU budget for 2017, in reality EUR 426 million or 0.3% of the total budget were realised as actual payments.

When it comes to the overall cost evolution of the ITER project, there have been some significant delays and overruns. In the latest 2016 assessment approved by the ITER Council, the EU contribution up to 2035 is now foreseen to total EUR 13.6 billion in 2008 euros. A detailed breakdown of this funding, in current values, and as used in our modelling inputs is provided in chapter 2.

In the 2014-2020 window ITER is budgeted to receive EUR 3.3 billion in 2008 value, this will bring total EU funding since 2007 to EUR 6.5 billion (see Table 2-1). Meanwhile in the same EU financial period there is EUR 80 billion dedicated to **Horizon 2020** and within which the other non-nuclear (fission and fusion) low-carbon technologies are budgeted to receive funding of EUR 5.9 billion for research and innovation on sustainable energy[34]. This represents approximately EUR 850 million euros per year over

[29] ITER impact assessment interviews, February/March 2018
[30] European Commission, Multiannual financial framework 2014-2020 and EU budget 2014 The figures (https://publications.europa.eu/en/publication-detail/-/publication/d2cf202e-f36a-45b2-84e7-1ac6ad996e90)
[31] European Parliament, Briefing How the EU budget is spent September 2017, ITER, (http://www.europarl.europa.eu/RegData/etudes/BRIE/2017/608715/EPRS_BRI(2017)608715_EN.pdf)
[32] *Ibid.*
[33] *Ibid.*
[34] European Commission, Horizon 2020 in brief, (https://ec.europa.eu/programmes/horizon2020/sites/horizon2020/files/H2020_inBrief_EN_FinalBAT.pdf)

the 7 years of Horizon 2020. Most of the EUR 5.9 billion is to be invested in topics such as greater energy efficiency, technological breakthroughs in renewable energies, decarbonising the use of fossil fuels and the overall integration of the energy system.[35] At the same time Horizon 2020 also includes EUR 1.6 billion for nuclear research, split between fission and fusion, with the former taking the largest share. The fusion share of this budget of EUR 440 million is used to fund the EuroFusion research, related to, but separate from ITER. This represents only 0.55% of the total Horizon 2020 budget.

This demonstrates that ITER and fusion energy receive significant funding from the EU budget. Although it should also be noted that other low carbon technologies benefit much more from national, regional and private investments in the research and development of these technologies, which significantly multiply the actual amounts spent on renewables such as wind and solar. In this sense fusion energy compares relatively poorly.

It was originally requested that this work also reviewed the impact of a non-ITER scenario, if funding were stopped. Setting aside the practical and legal limitations to such a scenario one of the biggest costs of this approach would be the much reduced possibilities for the EU and its industry to benefit from the investments made to date in fusion energy. Effectively these investments would be written off. Nevertheless it was also decided in agreement with the European Commission that as this issue was to be explored much more in-depth in the parallel Impact Assessment study and that the resources allocated to this issue (a small part of 10 man days for the entire section 4.2) would be reallocated to a (simple) quantitative analysis of spin-offs using the E3ME model. The results of this are presented in sections 3.2.2 and 4.1.2.

4.2.3. Impact of ITER funding in the context of other past and present low carbon energy research and innovation investments

In this context it is useful to consider how the impact of ITER funding compares to the impact of EU funding of other low carbon energy technologies. Yet this issue also becomes complex, as it is not realistic to compare the impact of current EU research funding of mature renewable energy technologies such as wind or solar, as these are at a much more advanced stages of development and deployment. It would be more appropriate to compare the impact of ITER funding with funding of these technologies when they were at a similar experimental research and development stage. This means going back a few decades, for which information and analyses of this type are limited. Indeed for the European Commission this question of impact is also an open question, one that is being addressed for the first time through a current study also being carried out by Trinomics on behalf of DG RTD into the ‘Impacts of EU actions supporting the development of renewable energy technologies’. This study will assess the various impacts of energy research spending over the last 20 years, unfortunately it does not report in time to provide inputs into this work.

There are some things that can be identified which are relevant to this comparison. These include another important factor which has come up in the interviews is that research and innovation in renewable energy also benefits from dedicated national (and sometimes also regional) finance for research through university research centres, national incentive schemes or other means. There is also significant private sector investment in the more mature renewable energy technologies. As a result,

[35] https://ec.europa.eu/research/energy/index.cfm?pg=funding

the renewable energy R&D field is more decentralised, whereas European fusion research is primarily focused on the ITER project and receives its funding through the Euratom contributions.

With regard to growth and employment targets, interviewees consistently stressed the fact that ITER should not be viewed as the construction of a future power plant, capable of generating electricity but rather as a research project, similar to CERN. In this respect the potential direct economic benefits might not be a relevant indicator for measuring the success of the project. This also reflects the potential contributions expected from ITER concerning the European climate and energy targets. Being an experimental research facility, means that ITER will not have a significant direct impact on reaching the targets set for decarbonisation up to 2050. However, the nature of the project and the potential spin-off technologies, alongside the eventual scaling up and commercialisation of the fusion technology post-2050 mean that ITER could have an important role to play as a major catalyst for European energy transition, and in potentially sustaining a low carbon future post 2050.

4.3. In the context of Big Science

Apart from its future potential for the European (and global) power mix, ITER remains a large, complex and unique scientific and infrastructure challenge. This classifies it as a Big Science project together with similar undertakings at the scientific frontier.

There are a number of Big Science projects currently being carried out that, as with ITER, heavily involve European industry in their design, construction, and subsequent experimentation phases. The most important of those projects in terms of size, complexity, and potential for European science are loosely connected via the EIROforum[36] – an organisation that seeks to foster synergies in Big Science. F4E became a part of this forum in 2017[37] and is the EIROforum member with the third largest budget. Table 4-9 provides an overview of the most important European[38] Big Science projects stating the average annual *European* contribution to their budget, their staff numbers, and their main contributors.

[36] Available at: https://www.eiroforum.org/
[37] Eurofusion (and hence the JET tokamak) had already been part of the association.
[38] Based in Europe or primarily funded by European countries/institutions – part of EIROforum.

Table 4-9: Overview of most important European Big Science projects

Big Science project	Average annual budget (EUR)[39]	Staff	Main contributors/MS	Function	Comment
European Space Agency - ESA[40]	~ 5.5bn	~ 2 200	22 European countries	Organisation to continuously develop European space capabilities.	Also includes 1 EU associate member and Canada as a frequent co-operator. European Commission provides roughly 20% of budget.
European Organisation for Nuclear Research - CERN[41]	~ 1bn	~ 2 500	22 European countries & Israel	Research centre for fundamental physics.	Also includes 4 non-European associate members.
ITER[42]	~ 540M	~ 800	European Commission, 1 European country & 7 non-European countries	Largest nuclear fusion reactor in the world.	European funding is managed and disseminated via F4E. European contribution is 45% of total cost. *Still under construction.*
European Southern Observatory - ESO[43]	~ 230M	~ 730	16 European countries	Organisation with the world's most productive astronomical observatory.	Brazil's membership is pending.
European Spallation Source - ESS[44]	~ 150M	~ 400	12 European countries	High-power neutron spallation source.	Membership discussions ongoing with 3 European countries. *Still under construction*. ESS became a European Research Infrastructure Consortium (ERIC) in 2015.
European Synchrotron Radiation Facility - ESRF[45]	~ 100M	~ 670	12 European countries & Russia	World's most intense X-ray source and centre of excellence for fundamental research in living	Also includes 6 EU associate members and 2 non-EU associate members.

[39] European contribution (e.g. from institutions, EU member states, EEA countries etc.)
[40] Available at: http://m.esa.int/About_Us/Welcome_to_ESA
[41] CERN (2017). CERN Quick Facts 2017. Available at: http://cds.cern.ch/record/2274789/files/CERN-Brochure-2017-003-Eng.pdf
[42] IO (2017). ITER Annual Report 2016. Available at: https://www.iter.org/doc/www/content/com/Lists/list_items/Attachments/744/2016_ITER_Annual_Report.pdf
[43] ESO (2017). Annual Report 2016. Available at: https://www.eso.org/public/archives/annualreports/pdf/ar_2016.pdf
[44] ESS (2014). Introduction to the ESS project. Available at: https://www.stfc.ac.uk/files/introduction-to-the-ess-project/
[45] Available at: http://www.esrf.eu/home/UsersAndScience/Publications/Highlights/highlights-2015/facts-and-figures.html

Big Science project	Average annual budget (EUR)[39]	Staff	Main contributors/MS	Function	Comment
				matter science.	
European X-Ray Free-Electron Laser - XFEL[46]	~ 85M	~ 300	11 European countries & Russia	Ultrashort X-ray flashes.	Started operation in 2017.
Institut Laue-Langevin - ILL[47]	~ 80M	~ 500	14 European countries & India	Service laboratory which operates the most intense neutron source in the world.	Main European source of neutrons until completion of ESS.
European Molecular Biology Laboratory - EMBL[48]	~ 71M	~ 1800	23 European countries & Israel	Europe's flagship laboratory for the life sciences.	Also includes 2 non-European associate members.
TOTAL	~ 7.8bn[49]	~ 9 900			

[46] Available at : https://www.xfel.eu/facility/overview/facts_amp_figures/index_eng.html
[47] Available at: https://www.ill.eu/about/ill-faq/
[48] EMBL (2017). EMBL Programme 2017-2021. Available at: https://www.embl.de/aboutus/communication_outreach/publications/programme/programme17-21.pdf
[49] It should be noted that this amount is not comprehensive in a sense that it does not covers all Big Science projects currently active in Europe. A number of lower-scale projects were omitted here; these include: various synchrotrons (ALBA, MAX IV, DESY), research institutes (PSI, SCK-CEN), and projects with a significant share of non-EU participation (SKA).

As can be seen from the table above, ITER represents an important contribution to Big Science in the European comparison. No other project includes the same number of supporting countries, and only three projects employ more people. Among the projects listed above, it has the third largest European budget (7% of total European Big Science spending). To further underline its importance, ITER is only one of two Big Science projects (together with ESA[50]) that receive financing directly from the European Commission under MFF budget lines[51]. Apart from its significant financial volume, ITER can also be classified as a political priority due to its (potential) future impact on crucial issues such as energy dependency and climate change.

The following sections assess ITER according to its direct and indirect impacts and put those into perspective by comparing them with the impacts of other Big Science projects. Particular focus is placed on the comparative relevance of these projects for European industry.

4.3.1. Comparison of impacts

The impacts of European ITER spending on European employment, GVA and competitiveness have been discussed in detail above. In an effort to allow for an adequate comparison of ITER impacts with other Big Science projects, two organisations were singled out as comparators: CERN (Large Hadron Collider) and ESA (ISS, Ariane 5 & Vega, Copernicus).

The complexity and unique nature of each Big Science project makes it difficult to compare them with each other. Each of the chosen projects for comparison share a different specific characteristic with ITER. This allows some comparison of impacts across Big Science projects and hence establishes an additional angle of analysis for ITER's European achievements so far.

CERN (Large Hadron Collider)[52]

Although CERN was established in 1954, probably its most famous and capital-intensive project to date is the Large Hadron Collider (LHC). The LHC is currently the largest particle accelerator in the world. Construction of the LHC began in 1993 and lasted until 2008/2009, at which point the machine was completed and started operating[53]. In terms of its 'Technology readiness level' (TRL)[54], the LHC (TRL 8-9) is far beyond the nuclear fusion technology developed at ITER (TRL 1-3). Furthermore, the two projects differ in scope as the LHC is focused on fundamental research and ITER on solution-oriented research[55].

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[50] The programmes GALILEO and COPERNICUS, implemented by ESA, are two of the EU's flagship programmes. Commission funding (roughly EUR 1.3bn annually) covers their annual operation as well as implementation of smaller projects implemented by ESA under Horizon 2020. Available at: http://m.esa.int/About_Us/Welcome_to_ESA/ESA_and_the_EU2

[51] All other projects have an intergovernmental setup.

[52] Focus will lie on the Large Hadron Collider (LHC) rather than CERN as a whole in order to facilitate the comparison between projects (given that CERN has existed for over 70 years).

[53] Available at: https://home.cern/topics/large-hadron-collider

[54] See https://www.nasa.gov/directorates/heo/scan/engineering/technology/txt_accordion1.html for more information about TRLs

[55] Framework for assessment of scope of the different Big Science projects throughout this section is built on: Autio (2014). Innovation from Big Science: Enhancing Big Science Impact Agenda. UK Department for Business Innovation and Skills. Available at: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/288481/bis-14-618-innovation-from-big-science-enhancing-big-science-impact-agenda.pdf

A common point between the two projects is their large infrastructure nature and their high construction cost. At the end of its construction in 2009, the LHC had reached a cumulative budget of EUR 7.5bn[56]; the ITER reactor is expected to cost up to EUR 15.5bn only for the EU share (45% of the total) by the time it is finished in 2035[57]. In order to meaningfully compare the impact of the two projects, it is useful to focus on their respective construction phases.

A CERN representative[58] stated that no major economic impact studies were performed during the procurement phase of the LHC, and that focus was placed on finding meaningful case studies that could help support justification of the investment. Nonetheless, recent work by Florio et al. (2016b) assesses the broad economic impact of the construction of the LHC based on contract data provided by CERN. They have found that, in the long-run, profit margins of firms that have been involved in the construction of the LHC develop favourably. This is especially true for high-tech suppliers, while the effect for low-tech suppliers does not exhibit statistical significance[59]. This 'CERN effect' is also present, and will likely augment in size for industry involved in fusion, in the form of an 'ITER effect'. This manifests itself in the data and results at hand (positive and increasing GVA in European industry due to F4E contracts) as well as the case studies of Annex A (e.g. significant growth at Bruker Biospin [case study no.1] or pro-beam AG [case study no.4]). Whether or not this 'ITER effect' will be sustained beyond the construction phase (i.e. First Plasma) is, as was with CERN, a question of resource allocation and priority setting[60].

Case study example (No.10) Elytt Energy - the 'ITER effect' in action

Until recently, Elytt Energy's business depended almost entirely on projects coming from nuclear fusion projects, and ITER in particular. From an early stage on (2010) Elytt Energy was involved in F4E contracts as part of a consortium with Iberdrola IC and ASG. In 2015, Elytt Energy signed an 8-year contract of over EUR 30M to provide the Poloidal Field Coils Impregnation Tooling to ITER. Elytt Energy is leading the consortium that is executing the contract together with ASLYOM SAS and SEIV. Highlighting the continued importance of ITER for Elytt Energy's business, this contract has almost doubled the company's turnover in the years following the signature. Furthermore, it has helped Elytt Energy to optimize its international tendering process and gain worldwide reputation.

The PF Coils Impregnation Tooling contract, has helped Elytt Energy to gain traction internationally and with other scientific projects: Not only did the company's turnover go from EUR 5.66M in 2014 to EUR 11.8M in 2015 due to the new ITER contract, it also increased project volume managing capacity in magnets for particle accelerators (CERN) and favourably positioned Elytt Energy to win an EUR 12M superconducting magnets contract for the German FAIR project. Furthermore, F4E contract quality standards have helped Elytt Energy to successfully upgrade their processes and products and hence to be eligible for tenders from research institutions worldwide.

[56] Autio (2014). Innovation from Big Science: Enhancing Big Science Impact Agenda. UK Department for Business Innovation and Skills. Available at: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/288481/bis-14-618-innovation-from-big-science-enhancing-big-science-impact-agenda.pdf
[57] https://ec.europa.eu/energy/sites/ener/files/documents/eu_contribution_to_a_reformed_iter_project_en.pdf
[58] Personal communication via a phone interview in February 2018.
[59] Florio et al. (2016b). The Economic Impact of CERN Procurement: Evidence from the Large Hadron Collider. Working Paper no. 12/2016. Available at: http://wp.demm.unimi.it/files/wp/2016/DEMM-2016_12wp.pdf
[60] See chapter 4.3.3.

Another comparison that can be drawn between the two projects concerns their cost-benefit environment. Our modelling analysis (see section 3.2) suggests that in gross terms ITER was so far able to generate in GVA 93%[61] of the payments made as a result of the F4E procurement activities (excluding consideration of alternative spending of the same money). The GVA generated hence closely follows the monetary amount of funds paid out in F4E contracting activity. The already operating LHC demonstrates a significant net benefit, where the net present value (NPV) of the accelerator is estimated by Florio et al. (2016a) to be EUR 2.9bn over its lifespan from 1993-2025. The LHC's costs (both construction and operation) will hence be recuperated in full, and a significant economic benefit from the LHC will be achieved. The estimate includes benefits for industry (EUR 5.6bn), scientific knowledge (EUR 3.2bn), human capital formation (EUR 5.5bn), and the general public (EUR 2.1bn)[62]. The latter three effects are not modelled in the analysis presented in this work and are evaluated qualitatively, and therefore the modelling results are not directly comparable.

It can be assumed, however, that GVA cost coverage of the LHC's construction costs was not as efficient as is currently the case for ITER: as most of the LHC's benefits mentioned above were generated in its operational phase. Breaking even with the cost of construction is thus likely to have taken a few years of operating the accelerator, something that the ITER project is poised to avoid given its good current GVA/cost ratio. How exactly costs and benefits for ITER will ultimately shape out towards its scheduled decommissioning in 2042 is still unclear. Nonetheless, our modelling suggests that the (gross) GVA impact is already quite significant for involved firms, and that benefits to industry and human capital formation could add to this further. New scientific knowledge and general public benefits arising during the operational phase could also significantly contribute to the overall benefit of the programme.

ESA (Space Infrastructure)

ESA, much like CERN, cannot be characterised by just one specific project. Whereas the Tokamak in Cadarache, France is the centerpiece of ITER's efforts to make fusion energy feasible, ESA counts a broader range of flagship projects to support space operations. Nonetheless, there are similarities between ITER and ESA that make the two organisations comparable: For one, they both promote solution-oriented project(s). Secondly, high-value infrastructure undertakings claim the largest share of their budget[63]. Three of these ES undertakings are assessed in more detail and compared to the outcomes of this study for the economic impact of ITER in Europe. ESA's involvement in the ISS (together with NASA), Ariane 5 (together with ASI[64]), and Copernicus (together with EC) programmes have provided continuous benefits to the European economy.

ESA spending has generated GVA in the European economy in the order of EUR 14.6bn (ISS)[65], EUR 26.8bn (Ariane 5)[66], and EUR 1.97bn (Copernicus)[67]. The multiplier effects of these projects lie between

[61] Calculation: EUR 4.79bn / EUR 5.13bn
[62] Florio et al. (2016a). Forecasting the Socio-Economic Impact of the Large Hadron Collider: a Cost-Benefit Analysis to 2025 and Beyond. Technological Forecasting and Social Change. Available at: https://arxiv.org/pdf/1603.00886.pdf
[63] Available for ESA at: http://www.esa.int/For_Media/Highlights/ESA_budget_2015
[64] Italian Space Agency (ASI for its abbreviation in Italian)
[65] PwC (2016). Socio-Economic Impact Assessment of ESA participation to the ISS programme. Available at: https://esamultimedia.esa.int/docs/business_with_esa/Assessment_of_the_socio-economic_impact_of_the_ESA_participation_to_the_ISS_Programme_Executive_Summary_Sept_2016.pdf
[66] PwC (2014). Socio-Economic Impact Assessment of Access to Space in Europe: An Ex-Post Analysis of the Ariane 5 and Vega Programmes. Available at:

1.4 for Copernicus and 2.2 for Ariane 5. Employment multipliers of these three projects hover around 2 (each new job supported in the space industry creates one additional job in the wider economy). According to the same methodology[68], this multiplier is currently 2.92[69] for ITER based on estimates above (see section 3.2). F4E contracting activity has hence been a powerful tool in creating additional employment in European industry.

These comparisons need to be put further into context. All three ESA projects are already operational, facilitating the generation of GVA in industry since a larger share of non-construction industry is now involved. The large GVA induced by investment into Ariane 5 is due to the project being exploited commercially. On the other hand, the relatively high employment multiplier for ITER is likely to be induced precisely by the fact that the project is still under construction, and that this requires more employment, at least while construction continues.

All in all, comparison between high-value infrastructure projects in Big Science and ITER remains a complicated task. No other project with a similar budget is currently under construction[70]. Most of the comparable projects have already been constructed, are operational, and exhibit net-positive benefits to society. Weak evidence from construction periods (e.g. the LHC) suggests that these kinds of projects only recuperate their investment in societal benefits once operational. This is when industry GVA, scientific publications, and general public benefits can solidify. GVA generated by ITER contracting activity, however, seems to keep pace with the invested amounts. If trends continue through to 2025, the cost of ITER could be recuperated in full very close to its completion date; and hence much faster than was the case for the LHC. In general, given the pathway of the assessed projects at CERN and ESA, it seems likely that ITER is also set for a development that will provide a long-term return on investment (post-2025).

4.3.2. Synergies for industry between ITER and other Big Science projects

Given the unique construction challenge of most Big Science projects, companies need to have the mindset and ability to deliver completely novel parts through innovative manufacturing[71]. This environment tends to help contractors improve their expertise and process flexibility for complex assignments. Being part of the supply chain for one Big Science project thus enhances the probability for a company to venture into another. Positive experience in executing contracts for F4E can provide companies with market reputation, know-how, and confidence to try and become a supplier for other Big Science projects[72]. Tacit synergies in the form of process design and management of complex tasks can therefore be exploited by industry players for business development across the range of Big Science projects.

Apart from the 'soft skill' dimension, a 'hard skill' dimension of synergies that proves beneficial to suppliers also exists. Technical expertise gathered in the manufacturing and design of, for example, radiation-hard parts or cryogenics, find applications across a range of Big Science projects (with slightly

https://esamultimedia.esa.int/docs/business_with_esa/D7_Activity_LAU_contract_4000110988_14_F_MOS_Executive_Summary_Revised.pdf

[67] PwC (2015). Study to examine the GDP impact of space activities in the EU. Prepared for the EC.

[68] If 100 jobs additional jobs in the space sector created 100 jobs in the wider economy, then the multiplier is 2.

[69] For 2017: 2500 additional direct jobs, 4800 additional indirect and induced jobs – see section 3.7.

[70] Which would further allow to put effects in the context of the current socio-economic environment.

[71] Personal communication with an industry representative via a phone interview in February 2018.

[72] Personal communication with an industry representative via a phone interview in February 2018.

different environments): Technologies that were developed for fusion are now, for example, being implemented at the ESS[73]; expertise gained in one Big Science project can work as a stepping stone to get a foot in the door with another[74].

Technical knowledge obtained while working on ITER therefore seems to facilitate entrance into other Big Science projects (or vice-versa). Especially in cryogenics, magnets, and superconductivity, synergies across projects exist and can be exploited by industry. As a result, even entire supply chains can be roughly the same across Big Science projects[75].

To illustrate this with a case, Box 1 shows the potential sectors with synergies between ITER and ESA. This list resulted from a joint mapping exercise conducted by representatives from both organisations.

Box 1 - Illustrative case: potential sectors with synergies between ITER and ESA[76]

- High performance materials (e.g. alloys, ceramics);
- Novel construction techniques (e.g. bonding, joining, forming, coating);
- Modeling, generation and transmission of mm and μm EM radiation;
- High reliability moving parts in extreme environments (e.g. vacuum, temperature, radiation);
- Remote handling (e.g. robotics and materials);
- Impact of mm and μm power coupling on reflective components and mitigation strategies;
- High-resolution metrology of remote components;
- Radiation effects on electronics and sensors;
- Radiation effects on materials (e.g. harmonising/merging databases);
- Ion beams sources and acceleration (NBI ion thrusters);
- Use of high temperature superconductors in magnetic field generation (for spacecraft ionized particle 'shields');
- Cryogenic system development and cryogenic engineering;
- Sensor development (e.g. sensitive, gated detectors in the IR or UV);
- High temperature/high heat load testing of materials;
- Management best practices.

Whether or not this list will be used by ITER/ESA management and technology transfer teams to develop a synergy support system for industry remains unclear. However, it clearly shows that a multitude of technologies can find application across Big Science projects and that there is large potential for industry to harness those synergies.

A third avenue via which synergies can be created is through partnerships. A valuable factor of working on a Big Science project like ITER is, for example, the network of associated industries that comes with it. Through events like the Big Science Forum possibilities can be explored with new partners working on ITER or other Big Science projects to combine efforts on innovation or jointly establish spin-offs

[73] Personal communication with an industry representative via a phone interview in February 2018.
[74] Personal communication with an industry representative via a phone interview in February 2018.
[75] Personal communications with Big Science representatives via phone interviews in February 2018.
[76] Personal communications with Big Science representatives via phone interviews in February 2018.

outside of Big Science applications[77]. Beyond its economic value, these partnerships also tend to enhance and improve intercultural communication. As Big Science projects are big international undertakings, especially small companies involved often need to adjust to the new environments: Feedback from case studies suggests that employees quickly become used to the international environment and typically embrace the atmosphere it creates at the work place. Looking beyond cultural differences and realising the common goal that is being worked towards can help the employees become more accepting[78]. Fault lines can still arise, but this is only in a few select cases were the vision of companies can end up clashing significantly[79]. It is therefore not purely based on cultural differences that a partnership might turn sour.

Case study example (No. 9) VTT - technology transfer, networking and synergies

VTT work on various aspects of ITER, including remote handling for the divertor. It has created significant intellectual property (IP) as a result of its work on ITER, but not patents as these are more difficult for it to follow up. Nevertheless VTT feel that the IP that is generated through the work on ITER will provide good opportunities for future exploitation. This type of knowledge and competence development is a key driver of VTTs interest in working on ITER.

It was noted in interview that the role of industrial liaison officers (ILOs) is important to the ability of firms and institutions such as VTT to take full advantage of the IP and innovations developed as part of working for ITER. The difference in impact between Finland and Sweden was highlighted, with a more generously resourced approach in Sweden in the last years leading to greater involvement and success of its domestic industry in ITER contracting.

VTTs work on fusion energy involves close cooperation with universities like Aalto university, University of Helsinki and Tampere university of technology (TUT) with which there are close physical proximity and a long-standing relationship. Since working on the ITER projects the range of firms that VTT has worked with has increased as they have joined larger international consortia. This type of working has expanded VTTs network with companies in Germany, Spain, Italy and the UK. VTT see this expansion of partnerships and network as one of the main reasons for, and benefits of, being active in ITER.

VTT noted that they have similar experiences, for example in the possibilities to create IP, from working on other Big Science projects such as CERN, and which provided similar benefits 10 years previously. There can be good synergies for organisations such as VTT from working on these projects as they often have similar set-ups. VTT see the Big Science market as a larger international high-end type service opportunity area for universities, research institutes as well as industry, small or large, and which will create synergies that ITER can benefit from.

4.3.3. Technology transfer and dissemination for Big Science

Given the financial volume of the investments made on ITER, sound management of public perception of the project is paramount to secure funding in the long-run. It is crucial to open up to the public and

[77] Personal communication with an industry representative via a phone interview in February 2018.
[78] Personal communication with an industry representative via a phone interview in February 2018.
[79] Personal communication with an industry representative via a phone interview in February 2018.

to get both the general public and industry on board to support one's undertakings[80]. Insights from interviews with ESA and CERN (two projects with comparable financial responsibility) are used to provide a comparison of technology transfer and general public involvement with ITER.

Technology Transfer (Industry)

ESA utilises a multi-faceted technology transfer program that incorporates a broad patent portfolio and a unique push-and-pull system. On the one hand, 16 so-called 'Technology Brokers' stimulate technology transfer by pushing aerospace technology into non-aerospace markets. On the other hand, 20 incubation centres across Europe offer start-ups and existing companies the opportunity to further develop products from aerospace technology under their own initiative. It took many years to establish this system, and it is an expensive task to maintain it. Nonetheless, it helps significantly in spreading ESA's mission and to increase reputation and trust with industry[81]. Apart from ample IP development in industry (companies keep ownership of the IP if contracted by ESA), ESA further manages around 450 of its own patents for 150 inventions.

CERN's Knowledge Transfer programme prefers to license technology rather than give out the rights to use it for free. This commercialised push-system generates royalties for CERN's technology transfer (TT) team: It is basically self-sustaining and does not rely on the CERN budget. Royalties are collected in a TT fund and finance its operations. The pull element to the system is more centralised than in the case of ESA: Scholars, students, and industry are invited to come and use the infrastructure and innovate on-site in Geneva[82]. CERN tried to build up a decentralised network with multiple incubation centres like ESA but failed to do so due to high costs.

ITER is currently still in the construction phase which means that the majority of innovations happen in industry rather than on-site. This means that the possibilities to build up a sophisticated and reciprocal TT system as present at ESA or CERN are limited. However, it is important to start early with laying the foundations. A possibility for ITER would be to try and install 4-5 brokers packaging technologies across industries and offering it for use in non-fusion applications[83]. If supplemented by demonstrator projects and follow-up events, industry can be made aware of the potential of fusion technology and the importance of the project. ITER is still seven years away from scheduled first plasma, therefore it is likely that only then will its technology transfer programme be able to achieve a scale comparable to ESA's or CERN's. Nonetheless, proactive action is advisable to keep industry interested in the project over the long construction phase.

General Public

Apart from industry, the general public needs to be made aware of the benefits to society that the project is providing now and can contribute to in future. This issue is heavily promoted by all Big Science projects, since they are frequently financed directly via tax-payers' money.
As a fundamental strategy, both ESA and CERN have opened their doors to the general public in the form of guided tours and on-site events. This provides people with a first-hand experience and can furthermore create a bond between individuals and the project[84]. ITER also offers this, and focus in

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[80] Personal communication with a Big Science representative via a phone interview in February 2018.
[81] Personal communication with a Big Science representative via a phone interview in February 2018.
[82] Personal communication with a Big Science representative via a phone interview in February 2018.
[83] Personal communications with Big Science representatives via phone interviews in February 2018.
[84] Personal communications with Big Science representatives via phone interviews in February 2018.

Cadarache should hence lie on continuously improving the visitor’s experience as well as actively marketing to the public the possibility of getting a glimpse into the world’s largest and most sophisticated nuclear fusion machine.

Additionally, just like ESA and CERN, ITER and F4E should continue to maintain a frequently updated social media presence with the goal of creating a positive public perception of ITER, similar to that of the LHC at CERN and ESA.

5. Conclusions and recommendations

Key conclusions

Based on the analysis we can draw the following conclusions on the impact of ITER to date and in future.

- **F4E spending on ITER is having a significant economic impact.** The results from modelling show that spending on ITER is delivering almost equal returns in increased GVA (almost €4.8 billion increase compared to €5.1 billion spent) in the EU economy. It has also generated around 34 000 job years between 2008-2017. These impacts are expected to increase, along with spending, in the next 5 years. So far, the geographical distribution of impacts largely correspond to the size of an economy, with a weighting towards France as the host country;
- **In comparison to an alternative spending scenario ITER delivers a net benefit to GVA and employment**, these total €586 million, and 1 000 job years over the full 2008-2030 period;
- **The net benefits are significantly increased by spin-offs and further innovation stimulated by firms working on ITER and developing new technologies and products,** whilst the modelling results are indicative, they suggest that impacts increase by 15-60% due to these effects. The case studies (e.g. Bruker, Pro-beam) also clearly demonstrate how either spin-offs or applications in new, non-fusion markets can occur and provide significant financial benefits to firms.;
- **F4E spending is having significant positive benefits for firms in a variety of areas.** Feedback from companies suggests that their work on ITER is helping them to develop new cutting-edge technologies, to improve their production and other processes, to access business opportunities outside of fusion, build synergies and new opportunities by encouraging consortium working and helping the great majority of firms to develop their technical knowledge and skills;
- **The modelled GVA gains show that ITER compares quite favourably on return on investment to other Big Science projects,** based on evidence from other Big Science projects such as CERN and ESA. ITER is already generating total gross GVA at almost a €1 to €1 ratio of input to GVA, with this including a multiplier of 2 or more for the indirect and induced GVA and employment impacts of ITER spending, i.e. the total impacts include the direct impact of ITER and an additional 2 or more euros of GVA or job years from the supply chain and other effects;
- **In the medium to longer term there is likely to be a positive return on investment from the EU commitment to ITER**. This is consistent with the economic assessment made here, which shows that there is already close to a 1-to-1 return, the indications given by firms and similar development pathways experienced at ESA and CERN;
- **It remains highly valuable to keep the ITER fusion power option open, as a large scale, low-carbon, clean, low environmental impact energy technology in which Europe can be self-sufficient.** Although fusion power will only play a major role in the energy system post-2050. It may be the 2060s or 70s before a commercial fleet of fusion power plants starts to be rolled out. Between now and then there are many uncertainties in the costs of fusion and other energy technologies, and the needs of the future energy system. Nevertheless, it is thought by most experts and the opinion of the authors that is highly valuable to keep the ITER fusion power option open, as a large scale, low-carbon, relatively clean (compared to nuclear fission), low environmental impact, energy technology in which Europe can be self-sufficient. Whilst the risks with the project are high, the potential benefits are also potentially very high

for ITER to act as a catalyst for the sustainable energy transition that will be necessary in the coming decades;
- **ITER should be seen as a Big Science project investment rather than energy research.** Whilst the goal is to contribute to the development of a commercial fusion power technology this remains so far into the future that it is not a key driver for ITER, this would rather be a stronger driver for DEMO;
- **Opportunities and synergies with Big Science.** It is possible to learn from other more advanced projects such as ESA and CERN on how to enhance the public profile of the ITER project and to support technology transfer. Specific technological synergies are already identified with ESA and could be further developed.

Recommendations

We were asked to provide recommendations focused on the dissemination and improvement of ITER impacts and we suggest the following:
- **Already begin to systematically invest in technology transfer.** The experience from both the LHC at CERN and ESA demonstrates that setting up an effective technology transfer system takes time but is crucial to enhancing the impact of the public investment. It is also important to reduce the chances that EU investments in the technology development result in sustainable economic gains and not (as in the case of Solar PV) that EU money kick-starts the development of the technology but the industrial production and benefits largely occur elsewhere. Further work to examine the best option for such a mechanism for F4E and ITER would be beneficial as the approaches taken by ESA and CERN differ considerably and each have particular strengths. Either way, steps need to be undertaken as soon as possible to build up a technology transfer system, so that it can support innovation and guarantee the continued generation of societal benefits from ITER through its operational phase;
- **Develop a strategy to create a positive public image of ITER and fusion energy.** It is very important to create a positive public image of fusion energy for the future success of the project. This is something that other Big Science projects such as CERN and ESA have managed to achieve, and which helps in budget discussions. ITER and F4E should plan more clearly what it will do to engage the public in this way. In our view, important routes for doing so are:
    - Be clear about the time horizon for ITER as only being able to deliver a substantial contribution to the energy system post-2050. Position fusion as much as possible as a big science project that contributes to fundamental human knowledge next to already delivering concrete spin-offs and benefits to society;
    - Position fusion as a fossil-free (baseload) energy source complementary to, not a competitor with, already existing intermittent renewable energy sources such as solar PV and wind;
    - Be as open as possible about benefits and real and perceived risks of the technology;
    - Dedicate a substantial budget to informing the public about fusion energy, not only developing dissemination fact sheets, but also engaging and organising public debate in all Member States that discusses potential risks and drawbacks of the technology, by, for example, organising site visits;
    - Cooperate as much as possible with other big science projects to set up an effective technology transfer system.
- **Position fusion energy as clearly as possible in a post-2050 energy system, stressing its benefits in complementing renewables, its environmental benefits and reduction in energy**

dependence. Although there remain considerable uncertainties in what a post-2050 energy system will look like it remains important to position fusion energy within this to maintain its relevance.

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Annex A: Case studies

Case study selection

The case studies were selected in partnership with DG ENER and F4E, and also drawing upon the responses to the survey which asked if respondents would be willing to cooperate as a case study. This led to a longlist of around 30 firms as possible case studies. Each of these were approached and from this those that were able to cooperate were interviewed and with the support of desk-research a case study was drafted.

The case studies

Case study 1: ITER benefits medicine, life science and materials analytics (Bruker Biospin)

The company

Bruker Biospin is one of the subsidiaries of Bruker Corporation, with worldwide more than 6,000 employees at 90 locations. Bruker delivers the world's most comprehensive range of research tools enabling life science, materials science, analytical chemistry, process control and clinical research. Bruker is also the leading superconductor magnet and ultra-high field magnet manufacturer for NMR and MRI solutions. Bruker Biospin, specialising in Magnetic Resonance & Preclinical Imaging, has some 61 offices over all continents.

Main case-study characteristics

The ITER contract involves the delivery of niobium-tin strands for the superconducting magnets used to confine the plasma at ITER. The experience gained at ITER has contributed to making niobium-tin the standard for high-end Nuclear Magnetic Resonance (NMR) and Magnetic Resonance Imaging (MRI) technology, and helped to make Bruker Biospin a world leader in these fields. The contract came about through a long-standing research cooperation between Bruker and the Karlsruhe Institute for Technology (KIT) that still continues today. NMR and MRI are widely applied for research and imaging in medicine, life sciences and materials analytics.

Main characteristics	
Company	Bruker / Bruker EAS
Country	Worldwide / Germany
Contract title	Supply of Chromium plated Niobium-Tin Strand (OPE-005)
Contract value	EUR 22.8M
Contract period	2009 - 2014
ITER Component	Magnets
F4E Work Package Code	11

Description

Nuclear fusion at ITER requires superconducting magnets able to confine the ultrahot plasma in which the fusion processes take place. New materials have to be developed for these magnets which can be applied in a wide range of analytical applications that can be used in areas varying from medicine and life sciences to materials analytics.

In ITER, 18 coils will shape a magnetic cage responsible for keeping the plasma away from the walls of the vessel. Europe has been tasked with the production of 10 of these so-called 'Toroidal Field coils' (one of which will be kept as spare), whilst Japan will manufacture the nine others. Bruker Biospin, is responsible for producing the specific niobium-tin strands for the coils. In 2009, Bruker EAS was awarded by F4E a contract for the procurement of 37 tonnes of niobium-tin superconducting wires, worth EUR 24,5 million.

Main impacts

New business opportunities

Supplying ITER with niobium-tin superconducting strands, Bruker Biospin improved its own tin wire manufacturing process: the company had to overcome technical issues in terms of strand quality, which triggered improvements in the whole manufacturing line: yield, stability and quality. This know-how helped in increasing the yield and quality of the tin wire manufacturing process and enhanced process stability. The tin wire required for ITER procurement were of higher quality than wires normally produced by Bruker, notably in terms of external roughness.

In 2016, Bruker held a share of about 10% in the global superconducting wires market, valued at US$ 638.1 Million in that year. In the same year Bruker also acquired Oxford Instruments, holding another 8.8% of this market. As a result of the ITER contract, Bruker was able to improve its knowledge on the application of superconducting strands, which contributed to its use in other analytics application fields - in particular MRI and NMR. In these markets Bruker is one of the main actors, with clients for instance including Siemens, CERN, Philips, General Electric and Mitsubishi Electric. The global size of the MRI market accounted for a revenue of US$ 6.6 billion in 2017 (€ 6.1 billion), and it is expected to grow at a rate of 6.6% during 2017-2022. With a revenue of $ 107 million in 2016, Bruker holds a share of 1.6% in this market. The NMR market amounted to 0.77 billion in 2016 and is projected to reach USD 0.95 billion in 2022. With a revenue of $0.56 billion in 2016, Bruker is the world leader in this market (73% market share).

Employment and growth

For the ITER contract, 12 people were hired temporarily. After expiration of the contract, these people have permanently joined Bruker Healthcare Business Unit. The team has spread the acquired knowledge in particular in Bruker's MRI business unit.

The ITER contract allowed Bruker to improve its manufacturing line and expand its production process. In 2009, Bruker Biospin manufactured and sold about 30,000 km of superconducting wires; the company now delivers more than 60,000 km of such wires per year.

Human capacity building

The specific requirements of the ITER contract improved Bruker's R&D capacity, and provided beneficial experiences to the teams involved in terms of troubleshooting and high-performance. The team members have since transferred methodology to other processes. Internal transfer of knowledge to other business units started immediately after the end of the project, as well as the hiring the temporary project staff as permanent staff by the MRI business unit.

Innovation and technology transfer

The ITER project contributed to niobium-tin becoming the standard for the current generation of high-performance superconducting magnets used for NMR worldwide.

Networking and synergies

The niobium-tin contract is the result of a long-lasting cooperation between Bruker and the Karlsruhe Institute of Technology, that already exists for decades. For the contract, Bruker fortified its existing cooperation with the KIT and also acquired in 2003 the superconducting wire producer Vacuumschmelze. More recently, in 2016 also the wire producer Oxford Instruments was bought, making Bruker now the largest superconducting wire producer in the world.

Conclusion

This case shows that a materials supply and development contract for ITER can also contribute to improving high-tech analytics in many other fields, including medicine, life sciences and materials analytics. The company in this case used the ITER contract to expand a market position in the field of superconducting materials. The knowledge generated in this way was used within the same company for improving its activities in other areas. Although the direct employment within the company generated by the ITER contract was limited, the ITER contract knowledge showed important for market expansion in MRI and NMR analytics. Also, new strategic collaborations were established for the contract which formed the basis for a now leading position of the company in the superconducting wires market today.

Case study 2: New technology patented for ITER leads to successful high-tech start-up (MAGICS Instruments)

The company

MAGICS Instruments NV is a spin-off company from KU Leuven and SCK•CEN (the Belgium Nuclear Research Centre). MAGICS' core competence lies in the design of radiation hardened integrated circuits, and more specifically in electronic devices that reliably operate in space and nuclear environments. MAGICS addresses customers' demands by offering ASIC solutions, customized IC design services or rad-hard IP licensing. Having started with the two founders, the company now has five employees.

Main case-study characteristics

Katholieke Universiteit of Leuven developed electronic chips for F4E that are able to sustain the radiation environment, convert the analogue data picked up by sensors to a digital format and transmit the information through a single wire. Two researchers of the University got a license for using the design of these chips and created the spin off called Magics. The license of the technology has allowed Magics to gain credibility and an entry point within the nuclear and space industry. In 2017 the annual revenue of Magics has increased 60% and its team has grown to 5 people. They are now targeting the global emerging markets with their radiation hardened ASICs for predictive maintenance, condition monitoring and smart robotics. Further strong growth of the company is expected for 2018.

Main characteristics	
Company	Magics Instruments
Country	Belgium
Contract title	In-Pile Creep Relaxation and Post-Irradiation Thermal Creep Testing (GRT-291)
Contract value	EUR 0.19M
Contract period	2012; 2016
ITER Component	Diagnostics
F4E Work Package Code	55

Description

In the frame of the ITER project a contract was awarded by Fusion for Energy, to a research group from KU Leuven and SCK•CEN who have been developing hardened integrated circuits capable of resisting high radiation environments, a key challenge that was identified and included in the Euratom Fusion Technology Program in the 1990s. The project triggered the creation of Magics Instruments NV in late October 2015, which commercialises hardened integrated circuits able to operate in radioactive environments.

Main impact

New business opportunities

As a result of the ITER contract, two students at KU Leuven started a new company that got the license to further develop radiation hardened chips. SCK-CEN and KU Leuven became the shareholders of this company.

While the biggest share of MAGICS' revenues still comes from ITER contracts (roughly 50% of the EUR 400,000 in revenue obtained in the 2017 financial year), the company has managed to gain a share in several markets where radiation hardened sensors can be useful, e.g. space and nuclear fission. The size of the hardened-circuit markets amounted to roughly USD 1bn in 2015.

Non-ITER clients of MAGICS are not to be disclosed, but are in the area of service suppliers (engineering firms) to nuclear power plant operators. The company's products outside ITER mainly facilitate remote handling for nuclear reactors and nuclear waste management. MAGICS products also find application in the space sector. Despite the fact that the products of MAGICS in theory could be also useful in defence industries, the company chooses for ethical reasons not to become involved in this market.

MAGICS seeks to increase their revenues to €1M in 2018 and to €3M in 2020. Main goal for 2018 is to venture into emerging markets (Russia, India, China). The company is currently setting up distribution and sales channels in these countries to make market entrance possible. MAGICS is also looking for further business opportunities in the space market, in particular also with emerging new commercial providers such as SpaceX.

Employment and growth

In 2017, the company employed five people. Aim for 2018 is to double the number of employees to 10 and further growth in the future is envisaged.

Human capacity building

The five employees of MAGICS are highly skilled and specialised in the companies' products offered.

Innovation and technology transfer

MAGICS started out developing micro-electronics for nuclear reactors (chips for remote handling robotics in radioactive environments). During the incubation phase at KU Leuven the founders of the company gained project experience with integrated circuits because of the Fusion for Energy contracts. This gave the business of MAGICS significant traction with other clients. As of 2017, MAGICS has provided 5 non-patented high-radiation systems on chip for ITER to control remote handling equipment and to read-out sensors in harsh environments. The company is now developing novel technology that brings machine learning/AI from the server onto the chip. This would put pressure off network bandwidth and improve e.g. condition monitoring and preventive maintenance in space and maintenance of new energy sources (ITER).

Networking and synergies

The ITER contract has been very important for MAGICS network and references. Big Science projects sush as ITER are 'early technology adopters'. This helps SMEs like MAGICS to design and improve their product in an incubator phase. ITER also serves as a 'Lighthouse Project' for MAGICS, providing the company with a significant reputation boost in the industry and with potential clients. The execution of the ITER contracts helps prove to potential clients that the technology works and that it can be applied.

Synergies and networking are fostered within the ITER ecosystem, e.g. in the ITER Business forums; http://www.iterbusinessforum.com/home.aspx?f_lang=en). The forums and events are also the places where consortia are formed, opportunities for knowledge-sharing in fusion arise, and where suppliers can showcase their novel technologies in workshops. MAGICS further still maintains close cooperation with SCK-CEN and KU Leuven in order to stay up to date with the latest technologies.

Conclusion

The MAGICS case demonstrates the use of ITER as an early adopter and incubator for new technologies to innovative start-ups. Its functioning as a lighthouse project further serves as a powerful reference to demonstrate to potential clients the value in practice of the technologies developed.

Case study 3: ITER benefits nuclear fission decommissioning (OTL)

The company

Oxford Technologies LTD (OTL) was founded in 2000 at Culham in the UK, it originated as a spin-off from the JET fusion research facility where they were the remote handling (RH) team. OTL delivered the world's first remote handling equipment to operate inside a nuclear fusion reactor. OTL, specialises in remote handling, complex plant assembly, ultra-high vacuum engineering and radiation-hard systems, and has state-of-the-art facilities for building and testing remote handling equipment.

Main case-study characteristics

OTL's involvement in ITER stems from their experience from JET. OTL has been awarded several ITER contracts mainly related to remote handling systems, but also including cameras and hard image sensors. OTL developed the ITER Remote Maintenance Management System (IRMMS) and the Remote Handling Code of Practice (RHCOP). Therefore, they have effectively set the RH methodology and standards for development of all ITER RH systems and RH compatible plant. In total, OTL are involved in four major systems and have received over 22 orders from F4E. The table below shows the main characteristics of the company and the contracts they were awarded by F4E. The contract values and period refer to the payment received by F4E, not the actual contract value and period.

Main characteristics		
Company		Oxford Technologies LTD (OTL)
Country		National / UK
Contract 1	Contract title	Development of radiation hard image sensor demonstrator for remote handling applications
	Contract value	EUR 3.72M
	Contract period	2012 - 2016
Contract 2	Contract title	Development of a front end rad hard BISS I/O module prototype
	Contract value	EUR 0.10M
	Contract period	2016
Contract 3	Contract title	Engineering support for the follow-up of supplier activities for the development and supply of the remote handling systems
	Contract value	EUR 0.09M
	Contract period	2016 – 2017
Contract 4	Contract title	Engineering support for the follow-up of supplier activities for the development and supply of the RDHS
	Contract value	EUR 0.09M
	Contract period	2016
Contract 5	Contract title	Feasibility analysis and proposal of conceptual solutions for IVVS/GDC deployment system
	Contract value	EUR 0.04M
	Contract period	2011
Contract 6	Contract title	Architecture requirements and development plan for a CMOSRAD-hard inspection camera

		prototype_DACC10548
	Contract value	EUR 0.02M
	Contract period	2017
Total contract value		EUR 4.07M
ITER Component		Remote Handling / Electronics
F4E Work Package Code		57 / 52

Description

The ITER project required a RH framework to develop a Multi-Purpose Deployer (MPD) for an in-vessel robot device capable of carrying and installing in-vessel components up to 4.5 tons in weight and carrying out remote tasks such as in-service inspection, leak localisation and testing, dust and tritium control and maintenance of in-vessel diagnostics.

Due to limited space and radioactivity inside the vessel, interconnected tools, manipulators and cranes have to be operated and inspected remotely. The information extracted from the maintenance works performed will be recorded by sensors scattered in the machine, and will help the operators gather data on the temperature, pressure and position of the equipment. For that reason, the past five years OTL are working along with KU Leuven in Belgium, on developing electronic chips that will be able to sustain radiation environment, convert the analogue input picked by the sensor to a digital signal and transmit the information through a single wire. The results so far are promising and the know-how is expected to have a positive impact on the development of other electronics to be deployed in the ITER device.

Main impacts

New business opportunities

Relying solely on Fusion was a high risk for OTL, and therefore they decided to diversify, to have contracts where they could use a wider range of skill levels with less risk.

OTL are now involved in projects in the areas of fusion and high-energy physics, and nuclear fission decommissioning which is their predominant sector and evolved from their expertise in fusion.

OTL have designed and built RH equipment for the decommissioning of the Dounreay nuclear site in the UK. They have worked in an area on the site that has been used since the 1950's for storing Intermediate Level Waste (ILW). OTL are also working at the Sellafield nuclear fuel reprocessing and nuclear decommissioning site in the UK, where they are building a technically challenging RH system for an above ground storage pond containing complex nuclear waste in skips. OTL are also working at the at the stricken Fukushima Daiichi nuclear powerplants which were catastrophically damaged by the flooding / tsunami disaster in March 201. OTL have been developing remote handling solutions for fuel debris retrieval, from three (of 4 on site) nuclear reactors. OTL's approach to RH in these complex nuclear fission decommissioning assignments builds on the expertise and technology they have developed for JET and ITER.

OTL's work outside nuclear decommissioning includes a recently completed project on the design of a remote hot cell and RH equipment for an ultra-high energy target station on behalf of CERN. Furthermore, OTL has established a collaboration with SCK-CEN, the Belgian Nuclear Research Centre, contributing to the MYRRHA project (Multi-purpose hYbrid Research Reactor for High-tech Applications).

In SCK-CEN's facilities in Mol, there is a transmutation facility that includes a particle accelerator, that takes waste from a Fast Breeder Reactors (FBRs) and treats it to dramatically reduce its half-life. This is another very technically challenging environment in which OTL is involved, where the RH takes place inside a liquid metal core, and in a hall that has very high levels of radiation and other contaminants.

Employment and growth

OTL has between 10 to 20 staff working on ITER/F4E tasks, depending on the flow of orders. During 2017, Veolia Nuclear Solutions (VNS-UK), which now owns OTL, hired ten highly skilled engineering graduates. In total, VNS-UK located in the former OTL HQ in the UK, currently employs more than 70 staff.

Human capacity building

OTL staff benefited by developing and enriching their expertise in very high radiation environments, including selection of components, that are radiation tolerant (cameras, motors, etc.) and are capable of delivering RH of high weight components with a high level of dexterity.

Innovation and technology transfer

OTL's approach to RH in nuclear fission decommissioning projects was based on their experience gained by participating in JET and ITER projects.

Networking and synergies

The OTL approach to solving challenging problems in hazardous environments has led to long relationships with companies in their chosen markets. In 2015, OTL was bought by an American company called Kurion, which was in turn bought along with other four companies by the multinational company Veolia, to form "Veolia Nuclear Solutions". Thanks to their expertise, OTL has assisted F4E in specifying and evaluating tenders. As mentioned earlier, OTL has established synergies with the consortiums responsible for the decommissioning of the Dounreay and Sellafield nuclear power reactors, CERN, SCK-CEN and Japanese companies.

Conclusion

This case study shows that equipment and technologies that are used for ITER can find applications in other areas of business where operation are done remotely, e.g. nuclear fission decommissioning. OTL utilised the expertise gained from participating in JET and ITER to develop an area of expertise. Although participating in ITER has not had a significant impact on the employment rate of the company, it gave them the possibility to establish new collaborations both in industry and research.

Case study 4: Welding ITER's vacuum vessel creates business opportunities and fosters European cohesion (pro-beam AG)

The company

Pro-beam AG is an SME based in Planegg, Germany. Pro-beam's state-of-the-art electron beam technology has enabled the company to venture outside of Germany and serve clients throughout Europe and the world. Apart from its three offices in Germany, pro-beam maintains a liaison office in France and counts with permanent site managers in China and the USA. For its customers, pro-beam designs and overviews the entire production process of the tailor-made products it delivers. This stretches from engineering and contract manufacturing down to the ultimate construction of plants.

Main case-study characteristics

Pro-beam got into contact with ITER officials at an early stage of the project (around 2001). As an SME, pro-beam would have most likely been too small to compete with bigger competitors for F4E contracts, had they not had the advantage of being involved from the conceptual phase on. The main F4E contract that pro-beam currently executes is for the vacuum vessel of the ITER reactor. In a consortium of 7 companies (AMW Consortium), pro-beam is responsible for the electron beam welding of five of the nine sectors to the vacuum vessel. This is being done on-site in Burg, Germany, with the help of a large K6000 chamber. Work on ITER (via F4E contracts) has helped pro-beam to upgrade their processes and develop novel welding machines that are now being commercialized.

Main characteristics	
Company	pro-beam AG
Country	Germany / Worldwide
Contract title	Supply of Vacuum Vessel Sectors (OPE-068-01)
Contract value	EUR 7.5M (for pro-beam)
Contract period	2010 – Ongoing (Consortium)
ITER Component	Vacuum Vessel
F4E Work Package Code	15

Description

In the tokamak design of a fusion reactor (as used in ITER), ultra-hot plasma spirals around in the so-called torus, or vacuum vessel (VV). The vacuum vessel thus houses the main reaction and serves as a first safety containment barrier. Given the size of the ITER reactor, the VV designed will have to be 4 times larger than in any other currently operating tokamak fusion reactor. This unique design and manufacturing challenge requires outstanding expertise in the welding of large components.

The European contribution to the VV consists of the supply of 5 out of the 9 sectors in which the VV is sub-divided. One single contract (OPE-068) and the consortium to which it has been awarded (AMW) will be responsible to deliver this European contribution to the IO. Pro-beam was sub-contracted by the consortium at a value of EUR 7.5M to weld the sections via their electron beam facilities.

Main impacts

New business opportunities

Fusion-related projects (ITER and JT60) at pro-beam have lead to a total turnover of roughly EUR 2.62M between 2013 and 2017. Furthermore, EUR 1.3M of turnover can be attributed to contracts with indirect ITER involvement over the same time span.

In order to weld the extremely large VV sections of ITER, pro-beam had to expand its facilities and built a second K6000 giant electro beam (EB) welding machine. This machine was duplicated for redundancy and capacity implications induced by the F4E contract. As it is unique in its size and complexity, the concept of the machine is being commercialized. So far, two of them have been sold at a price range of EUR 5M to EUR 10M depending on customization. The giant EB welding machine (K6000) finds further application in pro-beams aerospace business and has helped the company to develop a competitive edge for welding assignments in this market.

Pro-beam also developed a state-of-the-art welding machine that can weld under local vacuum (not the whole part needs to be put under vacuum). This machine was designed for and delivered to a French contractor responsible for manufacturing the radial plates of the ITER toroidal fields. This new welding machine has a value of >EUR 1M and will be commercialized by pro-beam in the future.

Employment and growth

Over 20 people have been hired by pro-beam as a result of the F4E contracts. These employees focus solely on fusion-related work and are generally technicians and engineers – some of which hold a Ph.D. It is crucial for pro-beam to secure its fusion business in the future (with new F4E contracts) in order to avoid having to let off some of these specialized employees.

Increased attention from the regional and national press due to involvement in ITER also helps raise pro-beam’s profile with engineers. This has helped the company significantly in the hiring process.

Human capacity building

Early involvement with ITER allowed the pro-beam staff to get used to the pace, complexity, and legal peculiarities of working on a Big Science/nuclear project. This long-term expertise has helped pro-beam maintain a competitive advantage in the bidding process for F4E tenders.

Innovation and technology transfer

So far, only 1 patent has been filed by pro-beam that stems from an F4E contract (magnetic foothold for the weld puddle).

Networking and synergies

Working on ITER has created a circle of around 10-15 partners, of which pro-beam has engaged with in a number of other projects outside fusion. Generally, ITER is a great reference for pro-beam and involvement in fusion grants the company access to a broad network of potential partners and interesting new contracts (via conferences, events etc.).

A great added value to the company is the possibility of creating international networks. Pro-beam sees ITER as a great opportunity to bring Europeans and internationals together and to benefit from the large variety of expertise that each nationality brings to the table. Apart from the technological aspects, ITER works as a crucial element for promoting European values by fostering cohesion and driving integration. ‘Fusion means – to bring together –‘, says director Dr. Thorsten Löwer, ‘and this applies both in physical and human terms to ITER’.

Conclusion

This case shows how manifold the positive impacts of an F4E contract can be for an SME. Not only did the contracts serve as a major revenue catalyst and growth accelerator at pro-beam, they also significantly drove innovation (in the form of two novel designs of welding machines) and reputation of the company. Apart from improving hard numbers, involvement in ITER also increased cultural awareness significantly and readied the company for further international cooperation in the future. SMEs like pro-beam can therefore strive from an ITER contract - if secured by the safety net of a larger consortium.

Case study 5: New dimensions for microwave tube applications developed through successful international cooperation at ITER (Thales)

The company

Thales Group has some 64,000 employees and operations in 56 countries. It serves five sectors: Aerospace, Space, Ground Transportation, Defense and Security. Thales Electron Devices (TED) employs some 2500 people at 8 industrial sites in France, Germany, Israel, china and the United States. TED has some 1500 customers and produces 2000 products[85]. Its electron tubes and transmitters are used as radio frequency and microwave power sources in a broad range of high-tech applications, including space, telecommunications, defense, radio and TV broadcasting, scientific research, medical therapy and industry.

Main case-study characteristics

Ignition of a fusion reaction in ITER requires a heating system capable of heating the plasma to 100 million degrees Celsius. To reach this level, the Wendelstein 7-X experiment needs highly efficient microwave gyrotrons which are capable of generating 1 MW full power. To reach this level, the Wendelstein 7-X experiment requires gyrotrons which are capable of generating full power for 30 minutes. This is more than one hundred times the duration of the pulses already achieved and meant advancing into an entirely new technological dimension. The process was pushed forward by the close cooperation between Thales Electron Devices (TED), the Karlsruhe Institute of Technology (KIT) and The Max Planck Institute for Plasma Physics (IPP)[86].

Main characteristics	
Company	Thales
Country	France
Contract title	Procurement of an industrial 1MW, CW Gyrotron Prototype at 170GHz (OPE-447)
Contract value	EUR 2.5M
Contract period	2008[87]
ITER Component	Electron Cyclotron Heating and Current Drive
F4E Work Package Code	52

Description

A contract between KIT and Thales was settled to develop and manufacture the series gyrotrons. The first step of this collaboration was the development of a prototype gyrotron for W7-X with an output power of 1 MW for CW operation at 140 GHz. The series gyrotrons (TH1509) were then ordered from Thales. The first in the series was tested successfully at KIT and then at the Max Planck Institute for Plasma Physics (IPP). KIT subsequently proposed some technical enhancements for the full series.

Thales successfully implemented these new concepts and achieved the series production of the TH1509 gyrotron. Over the course of this project, Thales made breakthroughs that stabilised the supply chain and improved the reliability and series production of microwave tubes in continuous operation[88].

[85] Thales Group website, https://www.thalesgroup.com/
[86] ITER website, Successful European collaboration on gyrotron prototype, https://www.iter.org/fr/newsline/-/2348
[87] ITER also has a variety of newer, but smaller contracts with Thales concerning the Gyrotron
[88] Thales brochure, Wendelstein Experiment

Main impacts

New business opportunities

The collaboration between TED, KIT and IPP resulted in a range of innovations. For the long-term operation of the microwave tubes, for instance, a new method for variable application of magnetic fields was developed by TED in order to react to local temperature variations. The method was patented by the institutes and can be used in a variety of other application fields[89].

Employment and growth

In total, around 10 people worked on the project.

Human capacity building

The knowledge gained by TED and its partners was specific for ITER, but also contributed to a broader knowledge of microwave tubes in general.

Networking and synergies

The ITER contract was performed in close cooperation with the Karlsruhe Institute for Technology, the University of Grenoble and the Institute for Plasma Physics in Greifswald (Germany). A close cooperation between the different research institutes was necessary in order obtain the results of the project.

Conclusion

The Thales case shows how a high-tech international research cooperation results in tailor-made technological solutions for ITER, parts of which find their way into a variety of military and civil applications.

89 IPP, Wendelstein 7-X und die Fusion – An der Grenze des technisch Machbaren, IPP Brochure

Case study 6: Engineering and architectural support to the ITER site induces process innovation (IDOM NS)

The company

IDOM is a large consulting, engineering and architecture company based out of Bilbao, Spain, with 40 offices all over the world. The company is owned entirely by its employees. Currently, over 3000 people work at IDOM worldwide. Although covering a myriad of sectors with their infrastructure business, IDOM also counts with a dedicated nuclear services department called IDOM NS. The main activities of IDOM NS are the provision of a broad portfolio of technical services and expertise both in nuclear fusion and fission. These include site assessment, planning & safety, engineering design, architectural design, project & construction management, and consultancy services.

Main case-study characteristics

IDOM was involved in the realization of ITER early on, signing a multi-million Euro contract with F4E in 2010 as part of the Energhia Consortium (including Halcrow Group Ltd and Altran Technologies). This contract entails support services in the day-to-day management of works related to construction of the ITER buildings, site infrastructure and power supply (for which F4E is in charge). This includes systematic follow-up of design and construction contracts in terms of technical, financial, quality and schedule aspects. Up until today, this contract has also had the most important impact on the company in terms of process innovation and optimization, as well as the forging of new international partnerships and business opportunities.

Apart from the large Energhia consortium contract, IDOM NS is also carrying out civil engineering (e.g., seismic, explosion and impacts, structural), mechanical, fluid dynamics and thermal-hydraulic analyses for ITER. It also provides engineering support for the TBM systems design and technological demonstration and renders general contract management services[90]. Since the Energhia consortium contract is by far the largest, however, it will provide the background for this case study[91].

Main characteristics	
Company	IDOM (IDOM NS)
Country	Spain / Worldwide
Contract title	Support-to-the-Owner Contract for the procurement of ITER Buildings (OPE-090)
Contract value	EUR 27.4M (to Energhia Consortium)
Contract period	2010 – Ongoing (Energhia Consortium)
ITER Component	Technical Support Services
ITER Work Package Code	ES

Description

Building ITER is a unique architectural challenge in that it is a first-of-its-kind fusion reactor in terms of size and complexity. Apart from the machine itself, this also requires specialized and sound

[90] In total, IDOM is carrying out 14 contracts for F4E.

[91] Attribution of benefits can hence not be guaranteed fully to the Energhia consortium contract. This case study nonetheless shows that involvement in ITER and contracting by F4E had positive implications for the business of IDOM NS.

management expertise of the procurement, design and construction of the general infrastructure belonging to the Cadarache facility:

Concrete and steel structure buildings (facilities such as HVAC), mechanical distribution (compress air, gases, liquids..), fire protection and detection, roads, fences, bridges, galleries and deep buried drainage, electrical substation (HV), and electrical load centers (LV and MV).

There is hence a myriad of buildings present on-site covering various activities such as controlling, training, storage, water treatment, drainage, and power conversion. Under the 'Support-to-the-Owner' contract, IDOM (in the Energhia consortium) was financed by F4E to oversee and manage the procurement, design and construction activities of said on-site buildings in the South of France.

Main impacts

New business opportunities

The most important innovation inside IDOM NS that resulted from F4E contracting is the coupling of different computer codes (e.g., nuclear, mechanical, fluid dynamics) and the procedures and tools devoted to safety. While providing the necessary flexibility and efficiency for ITER-related processes, these coupled tools, procedures and knowledge also turned out to find application in other IDOM business activities. Most predominantly, this was the case for the nuclear fission sector.

Nonetheless, IDOM does not plan to commercialize this process innovation. Rather, the company is using it as a competitive edge in bidding and sees it as a means to improve safety and customer experience significantly.

Furthermore, IDOM developed a way of doing CFD analysis for ITER that was later implemented as a facilitating tool in their nuclear fission activities - although it is not normally applicable there. Novel seismic calculation methodologies and dynamic analysis for ITER also turned out to create efficiencies across sectors and improved IDOM's work conducted on fission reactors.

Other direct new business opportunities induced by F4E contracts are harder to identify. Generally, however, involvement in fusion has raised the company's profile and lead to new business opportunities in Europe, India, China and South America.

Employment and growth

IDOM NS has created 25 new high-skilled jobs (5 PhDs) due to F4E contracting activity. Most of these employees hold degrees in mechanical engineering, computer science, fluid dynamics, civil works and thermodynamics. Minimum requirement is generally an engineering degree. The whole IDOM NS department has grown from 25 to 150 since 2010, but this is not entirely due to new business development in fusion. Nonetheless, involvement in ITER has raised IDOM NS's reputation with prospective employees which has catalyzed their business and hiring: several staff has been and is being hired as a direct consequence of IDOM's activity in ITER.

Currently, 20 IDOM NS employees are working on-site in Cadarache to execute F4E contracts.

Human capacity building

Involvement in ITER's complex tasks has promoted higher skill development of IDOM NS staff and has been a key selling point in IDOM's talent attraction programme.

Innovation and technology transfer

IDOM does not generally file patents or register IP. Apart from that, innovation and invention stemming from an ITER project become property of the client because this is a contractual requirement of F4E.

For process innovation, however, internal know-how has been generated. This includes technical review procedures for computational software, project management, and extra safety and quality checks.

Networking and synergies

IDOM NS has engaged with nuclear regulators in South America (especially in Chile) serving as a facilitator to help assess possibilities of their accession to the IO. This visibility of IDOM is a direct effect of working on ITER and doing business on the South American continent.

As a result of the successful Energhia consortium, IDOM NS further took part in other consortia executing F4E contracts. However, this did not always turn out positively due to differences in visions and difficulties to establish synergies. Only lately IDOM has embraced working in consortia again, however being selective with whom they choose as partners.

Conclusion

This case provides a good example how the complex and first-of-a-kind construction challenge of ITER induces firms to think outside the box and innovate heavily on their processes. Not only did this help IDOM NS adapt to ITER work, but it also created crucial efficiencies for the department in their business for other applications such as nuclear fission. This is a good example of how F4E contracting activity does not only benefit markets as a whole but also helps contracted firms to improve their operations significantly.

Case study 7: High-value ITER contract leads to internal synergies and opportunities for SMEs (Wood plc)

The company

Wood plc is a large multi-national conglomerate from Aberdeen, United Kingdom, consisting mainly of the recently merged companies Wood Group and Amec Foster Wheeler. The company boasts more than 400 offices worldwide in over 60 countries, and employs 55 000 people. Wood plc is traditionally an oil & gas company but has also ventured into the nuclear business. Hereby, Wood plc can provide full lifecycle support: from new nuclear development and plan operational support to waste management and decommissioning.

Main case-study characteristics

Wood is involved in several F4E contracts. The two main high value contracts are a EUR 73M neutral beam remote handling (NBRH) contract and a €11m First Wall Panels contract (in consortium with 2 Spanish companies Iberdrola and Leading Enterprises). The NBRH contract sees Wood in a position of integrator, which is a common role for them in the nuclear industry. In this role, Wood brings together small and big industry players to best solve the complex design and construction issues of the ITER machine (as is the case for the robotics of the NBRH system). Benefits from working on ITER surface mainly in the form of inter-departmental synergies at Wood. Furthermore, sub-contracting activity of Wood has helped SMEs to gain visibility in the broader ITER and Big Science environment.

Main characteristics	
Company	Wood plc
Country	United Kingdom / Worldwide
Contract title	Engineering Services and Supplies in the area of the Neutral Beam Remote Handling System (OMF-340)
Contract value	EUR 73M
Contract period	2015 - Ongoing
ITER Component	Remote Handling
ITER Work Package Code	57

Description

Wood is responsible for design, manufacture, testing, installation and commissioning of the neutral beam remote handling system. Since the project is at an early stage, all the work to date has been in the design phase. Work has involved: development of a delivery strategy; integration of multiple interfaces (there are more than 10 major handling systems incorporated with the system); design of a bespoke crane system primarily performed by Reel SAS, development of novel cutting and welding techniques for pipes, assessment of Operating Sequences for the equipment, and assessment of Remote Handling Compatibility. Wood is also assessing simulation techniques from a Dutch company Heemskerk.

Main impacts

New business opportunities

Wood has recently been formed by the purchase of Amec Foster Wheeler by Wood Group. This has brought a more recent focus on technology, and the potential to exploit it in other markets. So while

Wood acts primarily as a managerial facilitator and to date in NBRH is not directly developing technology, there is a desire to use technical innovation for new business opportunities. Procedural synergies are actively sought by Wood across departments that could eventually lead to augmentation of their current business.

Furthermore, Wood's favorable position close to the industry allows it to better identify SMEs as subcontractors to solve specific design challenges. Providing these smaller players with an avenue into the innovatively stimulating ITER environment, has led to new business opportunities for these companies in the form of spin-offs and spin-outs. Examples of businesses who have benefited from being subcontracted by Wood are MAGICS Instruments (see case 2 above) and Heemskerk Innovative Technologies.

Wood has won contracts supporting Reel for other nuclear power plants, as a result of the established relationship and work on NBRH where Reel are the supplier. This would not have happened without having worked together on NBRH.

Wood sees opportunities from application of the Remote Handling techniques and technologies to the decommissioning market. Many of the tools and instrumentation that will be used for NBRH could apply equally to environments limited to remote intervention because of radiation levels.

Wood is also more engaged in the Big Science market in areas such as ESS and CERN on the back of successes at ITER.

Employment and growth

In theory, there has been net recruitment at Wood due to F4E contracts, but this does not seem to be of relevant size. Most of the time, experts are sourced from within the company to work on an ITER project. Currently, 10-15 people are working full-time on the NBRH within Wood, while another 8-10 are employed with subcontractors. There are a number of other F4E projects also running such as First Wall Panels which employs another 3 people, the other contracts tend to be a handful of people on a task by task basis.

If new employees are recruited, the F4E contracts are generally great 'bait' for potential candidates as these contracts increase Wood's reputation and allow employees to work at the cutting edge of energy innovation.

Human capacity building

The NBRH project has been good for Wood to enhance the skill set of their employees, with greater requirements in areas such as Systems Engineering, Remote Handling design and CATIA design.
Two engineers have been specifically recruited with CATIA design skills for the project.
The project has also resulted in greater technical capability with ownership of licenses in Enterprise Architect and CATIA.

Innovation and technology transfer

Wood have not done any of this in NBRH to date. They have been involved with the commercialisation of radiation mapping software that was recently formally confirmed with a presentation made to Michael Loughlin of ITER to note it.

F4E have been good at ensuring Intellectual Property (IP) rights are considered and retained.

Networking and synergies

Value creation at Wood is achieved by exploring cross-departmental synergies that arise from F4E contracts. There is, for example, potential of integrating the remote handling processes from Wood's fusion business into their fission activities as well. Wood's expertise in managing complex projects enables them to effectively foster detection and development of these cross-sector synergies.
Links between the internal departments within the Wood business have been strengthened through the need to integrate the various offerings for the project. So links between the businesses in the UK and the office in Aix-en-Provence have been improved. The departments such as Advanced Reactors, Engineering Development, Structural Analysis, are working closely together, and this helps generally to increase productivity with other joint tasks.

The networking events from F4E contracts and bids, have enabled cooperative agreements between Wood and several other companies. It has also helped establish significant networks of business contacts that have been and are explored for future opportunities across the entire nuclear market. These contacts are borne out of discussions concerning future opportunities, or sharing experiences of working with F4E, and the difficulties that can entail. F4E are also good at running technical workshops for sharing ideas and learning, and this helps increase knowledge and understanding.

Conclusion

F4E contracts have provided Wood plc with a large variety of benefits, ranging from internal synergies to external new business opportunities. Most importantly, however, this case shows that work on fusion can help contractors to develop new expertise that is readily applicable and beneficial, also in other sectors. Furthermore, technical innovation from F4E contracts is unlikely to happen at Wood, due to its role as facilitator and manager. But precisely that role has enabled Wood to single out the best-quality SMEs in the market to perform the design and manufacturing work as sub-contractors. This not only allows these SMEs a way into F4E contracting, but at the same time fosters economic and technological progress at smaller levels of the economy.

Case study 8: Producing ITER's Poloidal and Toroidal Field Coils allows Europe to become one of the world industrial leaders in superconducting magnets (ASG Superconductors)

The company

ASG Superconductors is a manufacturing company specialized in superconducting and resistive magnets. Superconductors are able to withstand higher currents than normal magnets, such as the ones used in the ITER tokamak which have to contain the plasma. ASG Superconductors has acquired industry-leading know-how in the design, development, production, installation and testing of superconductive and resistive magnetic systems, cryogenic systems, superconducting solenoids and coils, magnets for cyclotrons and components for made-to-measure applications. ASG's skills go from design to production to the complete test of systems and magnets. The company's biggest know-how is the fields of research, nuclear fusion, particle physics, applications for energy and medicine and the magnet projects it is working on. ASG also focuses on other parts of the superconductivity market, namely healthcare (MRI and Therapy), fault-current limiters and application to energy production. The average turnover of the company is around EUR 35-40 million. ASG Superconductors employs about 170 people (including white and blue-collar workers). ASG also owns two smaller companies (based in Genoa): Columbus Superconductors and Paramed (specialized in medical systems associated with Columbus). With these two companies, the total staff amounts to about 230 employees.

Main case-study characteristics

ASG Superconductors was awarded the contract for the construction of the ITER Toroidal Field Coils as part of a consortium with Iberdrola and Elytt Energy (in 2010). The coils are under construction in a new 28,000 m^2 production facility in La Spezia, Italy.

In 2012 ASG was awarded another order for "Engineering Integrator" activities as part of work on the construction of the poloidal field coils (PF2-PF3- PF4 e PF5) and the cold testing of PF6.[92]

Main characteristics		
Company		ASG Superconductors
Country		Italy
Contract 1	Contract title	Full Scale Dummy Pancake/Prep (OPE-053)
	Contract value	EUR 156M
	Contract period	2010- Ongoing
	Consortium	Iberdrola Ingeniería y Construcción SAU, ASG Superconductors SpA and Elytt Energy SL
Contract 2	Contract title	Engineering Integration Services for the Supply of the Poloidal Fields Coils – PF2 to PF5 Coils (OPE-344)
	Contract value	EUR 27.5M
	Contract period	2013-Ongoing
Total contract value		EUR 183.5M
ITER Component		Magnets
F4E Work Package Code		11

[92] ASG Superconductors, ITER Poloidal Field Coils, (https://www.asgsuperconductors.com/doc/ITER-PFC.pdf)

Description

ITER Toroidal Field Coils

The fusion process in ITER involves two hydrogen isotopes, deuterium and tritium, heated to temperatures in excess of 150 million °C, forming a hot plasma. Strong magnetic fields are used to keep the plasma away from the walls; these are produced by superconducting coils surrounding the vessel, and by an electrical current driven through the plasma.[93]

The heat produced from the thermonuclear reaction by ITER, through proper heat exchangers (steam generators), will allow the production of electric power by a standard turbo-alternator group. The ITER device will operate with a system of superconducting magnets which relies on the Toroidal Field Coils, the Central Solenoid, the Poloidal Field Coils and the Correction Coils. Europe will manufacture 10 of the 19 Toroidal Field Coils, including a spare one, while Japan is responsible to produce the remaining nine. Winding packs of this size have never been manufactured before.[94]

The European Domestic Agency Fusion for Energy has signed a contract for the supply of ten winding packs for the ITER toroidal field coils with a European consortium that brings together Iberdrola Ingeniería y Construcción SAU, ASG Superconductors SpA and Elytt Energy SL.

The signature of this EUR 156 million contract is a significant step for the ITER Project and an impressive technological milestone given the fact that winding packs of this size have never been manufactured before.

ITER Poloidal Field Coils

The Poloidal Field Coils contribute to generating the magnetic field to control the plasma position, maintaining the plasma’s shape and stability inside the tokamak in order to provide the conditions for the fusion reaction. The Poloidal Field Coil system consists of six horizontal, circular coils placed outside the toroidal magnet structure. As their very large size makes it impossible to transport them, manufacture of four of the six Poloidal Field Coil will take place in the PF coil winding building, directly on the ITER site in Cadarache, France.[95]

This contract is the first of a number of work packages which will cover tooling and equipment necessary in order to manufacture and handle the components, as well as site and infrastructure, manufacturing and cold testing. These work packages are currently being prepared in order to provide F4E’s contribution of Poloidal Field Coils 2–6 (PF coils 2–5 will all be manufactured in Europe, while PF coil 6 will be manufactured in China, but cold tested in Europe; the Russian domestic agency will procure PF coil 1).[96]

Main impacts

New business opportunities

The work done in the context of ITER allowed ASG to develop knowhow and further specialise in the international physics market. Two years ago, ASG acquired a project related to the field of high-energy physics in Germany which will allow the company to further diversify its portfolio. This project will also

[93] ASG Superconductors, ITER Toroidal Field Coils, (https://www.asgsuperconductors.com/doc/ITER%20TFC.pdf)
[94] Europe signs contract for toroidal field coil winding packs, 22 July 2010, https://www.iter.org/fr/newsline/-/349)
[95] EU awards engineering contract for poloidal field coils, 22 October 2013, (https://www.iter.org/fr/newsline/286/1740)
[96] PF coils Engineering Integrator contract signed, 15 October 2013, (http://fusionforenergy.europa.eu/mediacorner/newsview.aspx?content=724)

allow to support the already developed technological processes. It will contribute to ASG Superconductors minimising the decline of production after the ITER contracts have been delivered by focusing on this new project.

The biggest investment realized by ASG Superconductors in order to be capable of delivering the components in the context of the ITER project was the EUR 60 million 25 000 m^2 production plant, built in La Spezia, Italy.

Employment and growth

According to ASG Superconductors, around 50 people work in the manufacturing of the toroidal field coils. They are based in the facility in La Spezia, Italy. Further to that around 10 more engineers work in Cadarache on the follow-up of production which has already started. In total 60 people are involved just in the design, manufacturing and construction of the toroidal field coils.

ASG Superconductors employs high-level engineers who have to be hired on a long-term basis and have to be provided with steady and constant amount of work. The professional growth policy and mission of ASG Superconductors is it to provide nuclear fusion experts options and possibilities in various fields in order for them to specialise in a wide range of applications.

ASG Superconductors is also involved and working on CERN related projects and activities, namely in the field of superconducting magnets.

Human capacity building

ASG Superconductors has managed to attract new engineers and further train and expand on the professional capabilities of their staff. Working on ITER related activities has also allowed ASG to further develop knowhow and successfully bid for other high-end physics related projects. The work done for ITER has also contributed to the increased competitiveness and recognition of ASG Superconductors on the international physics research and activities market.

Innovation and technology transfer

At this stage, no specific patentable knowhow has been reserved. There are ongoing queries on patenting a precise magnetic measuring technique, specially developed for ITER that can detect with great precision volumes of magnetism. It was developed through the research and development work done in the context of the two contracts for delivering Poloidal and Toroidal Coils.

Conclusion

The case of ASG Superconductors highlights the positive impacts that the ITER project has on stimulating the European high-end physics in general and the superconducting magnet industry, in particular. According to the company itself, at this point it is very difficult to envision how these technologies could be applied in the public sector. The activities carried out by ASG Superconductors as part of the ITER design, manufacturing and construction have allowed them to attract new staff and develop knowhow, enabling them to diversify the markets they operate in. It has also contributed to the construction of new manufacturing plant in the small Italian town of La Spezia, which has stimulated the local economy by attracting hi-tech and well payed jobs. Even though potential synergies with other companies, outside the consortium they are part of, have not occurred, the work delivered for the ITER project has allowed ASG Superconductors to establish itself as one of the main players in the global market for superconducting magnets. The research carried out by the company in the context of ITER also permits for the development of innovative materials. It also allows for the implementation of new research in particle physics, which can have potential spill-over effects for other industries.

Case study 9: Research institute has successfully found alternative applications and significant returns for technologies developed through work on ITER (VTT)

The company

VTT Technical Research Centre of Finland Ltd is a Finnish research organisation founded in 1942. Originally a public organisation it became a not-for-profit, state owned limited company in 2015. It employs more than 2,300 staff and has a total turnover of €258 million, of which €73 million comes from a government grant. It serves clients both public and private, and domestic and international. As a leading European research institute, it produces research in many different fields, but focused on the following key areas:

- Bioeconomy and circular economy
- Health and wellbeing
- Digital society
- Low carbon energy
- Smart industry – VTTs work on fusion energy is a combination of this area and smart energy systems (low carbon energy area).
- Sustainable and smart cities
- Business development
- Pilot plants and R&D infrastructure

In 2017 it was involved in 237 inventions, more than 1,400 patent applications and the publication of 610 scientific articles.

Main case-study characteristics

VTT have been involved with fusion energy dating back to 1995, and since 2001 has had continuous involvement in fusion energy related research through EFDA and then F4E and IO contracts. VTT is focused on multiple areas related to fusion energy, these include:

- Plasma physics
- Materials science
- Remote handling

VTT, with its close partner Tampere University of Technology (TUT), were selected to host the DTP2 research environment as part of the TUT international Remote Operation and Virtual Reality Centre (ROViR). This is an important source of work related to fusion energy in the area of remote handling related to the divertor. The main F4E contract identified in the dataset from F4E in which VTT is involved is a €70 million contract to a consortium led by Assystem UK.

Main characteristics	
Company	VTT
Country	Finland / Worldwide
Contract title	Preliminary Design of the DRHS-Phase 2 (OMF-340)
Contract value	EUR 70M (amount for VTT unclear – this value is for whole consortium led by Assystem UK) Involvement in multiple other F4E contracts since 2008, primarily related to remote handling and working closely with TUT.

Contract period	2010 – Ongoing (Consortium)
ITER Component	Divertor Remote Handling System
F4E Work Package Code	23

Description

As part of the operation of the reactor a divertor is used, this collects any hot ashes or impurities from the fusion reaction chamber. This divertor is made up of 54 large (3.4m x 2.3m x 0.6m) cassettes, each weighing 10 tonnes. These need to be removed for treatment and replacements inserted, with millimeter precision, using remote handling system. The DTP2 facility has been used to carry out design reviews, enhancements and demonstrations of the cutting edge remote handling technology being developed by VTT in partnership with TUT.

Main impacts

New business opportunities

VTT noted that by undertaking contracts for F4E it has been able to gain many more contacts in industry, and these are proving useful for exploiting new synergies and exploring new business opportunities across VTT as a whole, not just in the area of nuclear. Specific opportunities were identified in the areas of nuclear decommissioning, mining and the space industry.

It finds that most of its main technological developments and spin-offs tend to emerge from cooperation with universities, particularly, but not only, TUT. The process often involves the cooperation with universities in discovering or developing a particular technology or material and then to turn this into an application in the fusion sector and beyond. Examples of such technologies and their further applications include:

- A tool for the design of complex systems;
- Augmented and virtual reality tools – also used in the space industry;
- A new technology for cleaning dust from irradiated products – also used for surface treatment in metal industry, electronics, apart from nuclear);
- Sensor technologies (via F4E diagnostics contracts).

The latter two developments have been particularly successful, with the economic returns in the non-fusion sectors already surpassing the returns in the fusion sector. It was not possible to quantify these effects exactly, but a Principal Scientist at VTT felt that returns x2-3 bigger than the initial investment are being made, which compares favourably with other sectors in which VTT works.

Employment and growth

VTT employs around 50 people that work on fusion-related projects, with a relatively even split across the 3 main work areas of plasma physics, materials science and remote handling. The remote handling team is one specific example of employment growth, with the team employing only 2 people in 2005, having now expanded to 15 employees. This being driven by large grants from F4E for demonstration projects for remote handling including control system development and diagnostics.

Human capacity building

People working in fusion-related activities at VTT tend to have experience in the simulation of plasma physics, materials, and radiation environment applications, and are therefore highly skilled with

Masters degrees or PhDs. During the fusion projects several researchers have been able to upgrade their competences to PhD level.

Innovation and technology transfer

VTT has created significant IP as a result of its work on ITER, but not patents as these are more difficult for it to follow up. Nevertheless the IP that is generated through the work on ITER is felt to provide good opportunities for future exploitation, and this type of knowledge and competence development is a key driver of VTTs interest in working on ITER.

It was noted in interview that the role of industrial liaison officers (ILOs) is important to the ability of firms and institutions such as VTT to take full advantage of the IP and innovations developed as part of working for ITER. The difference in impact between Finland and Sweden was highlighted, with a more generously resourced approach in Sweden in the last years leading to greater involvement and success of its domestic industry in ITER contracting.

Networking and synergies

VTTs work on fusion energy involves close cooperation with universities like Aalto university, University of Helsinki and Tampere university of technology (TUT) with which there are close physical proximity and a long-standing relationship. Since working on the ITER projects the range of firms that VTT has worked with has increased as they have joined larger international consortia. This type of working has expanded VTTs network with companies in Germany, Spain, Italy and the UK. VTT see this expansion of partnerships and network as one of the main reasons for, and benefits of, being active in ITER.

VTT noted that they have similar experiences, for example in the possibilities to create IP, from working on other Big Science projects such as CERN, and which provided similar benefits 10 years previously. There can be good synergies for organisations such as VTT from working on these projects as they often have similar set-ups. VTT see the Big Science market as a larger international high-end type service opportunity area for universities, research institutes as well as industry, small or large, and which will create synergies that ITER can benefit from.

Conclusion

This case shows how technology institutes such as VTT have a key role to play in the development of the advanced technologies necessary for ITER. It highlights that this is creating multiple new business opportunities for the institute across multiple sectors that it is already active in. This type of work requires good international networks and cooperation with leading universities. VTT acknowledges the benefits of carrying out F4E contracts for ITER, placing particular value on the new markets, partnerships and competences that can be developed in doing so. It is able to provide examples of specific technologies already finding applications outside of fusion energy and which are delivering significant returns. The impact that institutes such as VTT, and perhaps F4E as whole, can have, is enhanced when sufficient resources are allocated to actively working with industry, for example through industrial liaison officers.

Case study 10: ITER contracts successfully create, sustain, and enhance business for European SMEs (Elytt Energy)

The company

Elytt Energy is an SME headquartered in Madrid, Spain, that provides engineering and manufacturing services to scientific infrastructure clients in the high-tech market. It has a special focus on business in energy projects (conventional, nuclear, renewables) and particle accelerators, where Elytt Energy is responsible for the design and construction of magnets and power supplies. The engineering work is performed in Elytt Energy's Madrid office, whereas the hands-on manufacturing work is executed at their Bilbao unit in the north of Spain.

Main case-study characteristics

Until recently, Elytt Energy's business depended almost entirely on projects coming from nuclear fusion projects, and ITER in particular. From an early stage on (2010) Elytt Energy was involved in F4E contracts as part of a consortium with Iberdrola IC and ASG. In 2015, Elytt Energy signed an 8-year contract of over EUR 30M to provide the Poloidal Field Coils Impregnation Tooling to ITER. Elytt Energy is leading the consortium that is executing the contract together with ASLYOM SAS and SEIV. Highlighting the continued importance of ITER for Elytt Energy's business, this contract has almost doubled the company's turnover in the years following the signature. Furthermore, it has helped Elytt Energy to optimize its international tendering process and gain worldwide reputation.

Main characteristics	
Company	Elytt Energy SL
Country	Spain
Contract title	PF Coils Impregnation Tooling and Additional Tooling (OPE-654)
Contract value	EUR 30.5M (Consortium)
Contract period	2015 – Ongoing (Consortium)
ITER IP technological area	Magnets
F4E Work Package Code	11

Description

The poloidal field (PF) magnets keep the plasma away from the walls of the reactor and help shape the form and stability of the plasma. The poloidal field is hence created both by the magnets and by the current drive in the plasma itself. The PF system in ITER consists of six horizontal coils placed outside the toroidal magnet structure.

Under the focus contract, Elytt Energy (and the consortium) will provide the tools to form and install said PF coils on-site in Cadarache. The tooling will be designed and manufactured by Elytt Energy and then shipped off to the ITER PF coils facility where it will be further assembled and tested. The delivery includes: mechanical equipment that can lift, insulate, and stack the layers of conductors; impregnation tooling to electrically insulate the coils via a vacuum; and, a gantry crane supporting final assembly that can lift up to 400 tons worth of material.

Main impacts

New business opportunities

Elytt Energy's turnover, until recently, could be attributed almost entirely to F4E contracts. The PF Coils Impregnation Tooling contract, however, helped Elytt Energy also to gain traction internationally and with other scientific projects: Not only did the company's turnover go from EUR 5.66M in 2014 to EUR 11.8M in 2015 due to the new contract, it also increased project volume managing capacity in magnets for particle accelerators (CERN) and positioned Elytt Energy favorably to win an EUR 12M superconducting magnets contract for the German FAIR project.

Furthermore, F4E contract quality standards have helped Elytt Energy to successfully upgrade their processes and products and hence to be eligible for tenders from research institutions worldwide.

Employment and growth

Almost the entire staff of Elytt Energy has been hired due to F4E contracts. The three big F4E contracts that Elytt Energy holds have significantly shaped the growth of the company throughout the years of its involvement.

Human capacity building

Contracting with F4E provided the employees of Elytt Energy with the capacities to manage, and prepare proposals for, tenders from international research institutions. Furthermore, new technical knowledge and skills regarding the design and manufacture of superconducting magnets are developed continuously at Elytt Energy due to contract execution for F4E. One example of this is learning to manufacture coils using cable-in-conduit, niobium-tin-based conductor technology.

Innovation and technology transfer

Elytt Energy has not created any intellectual property stemming from work conducted for F4E.

Networking and synergies

Working on F4E contracts has allowed Elytt Energy to join and to lead international consortia which, in turn, have led to a fruitful environment of partnership among the member companies.

Conclusion

This case shows how F4E contracts can significantly boost the development and growth of SMEs that possess the expertise to solve ITER-specific design and manufacturing challenges. A consortium can facilitate entry into such work, and sets the SME's learning curve on the right path to ultimately take on their own F4E assignments. Working on ITER was, and continues to be, a boon for Elytt Energy, as the company has experienced a staggering increase of its turnover due to being awarded various F4E contracts. Last but not least, the increased reputation gained from the assignments also provided Elytt Energy with international and outside-fusion business opportunities.

Annex B: NACE and country codings

Table B-1: NACE sector listing - as used in the E3ME model

Basic type	NACE Sector	E3ME Description
Primary production	A01	Crops, animals, etc
Primary production	A02	Forestry & logging
Primary production	A03	Fishing
Primary production	B05	Coal
Primary production	B06	Oil and Gas
Primary production	B07-09	Other mining
Manufacturing	C10-12	Food, drink & tobacco
Manufacturing	C13-15	Textiles & leather
Manufacturing	C16	Wood & wood prods
Manufacturing	C17	Paper & paper prods
Manufacturing	C18	Printing & reproduction
Manufacturing	C19	Coke & ref petroleum
Manufacturing	C20	Other chemicals
Manufacturing	C21	Pharmaceuticals
Manufacturing	C22	Rubber & plastic products
Manufacturing	C23	Non-metallic mineral prods
Manufacturing	C24	Basic metals
Manufacturing	C25	Fabricated metal prods
Manufacturing	C26	Computers etc
Manufacturing	C27	Electrical equipment
Manufacturing	C28	Other machinery/equipment
Manufacturing	C29	Motor vehicles
Manufacturing	C30	Other transport equip
Manufacturing	C31-32	Furniture; other manufacture
Manufacturing	C33	Machinery repair/installation
Energy & Utilities	D351	Electricity
Energy & Utilities	D352-353	Gas, steam & air cond.
Energy & Utilities	E36	Water, treatment & supply
Energy & Utilities	E37-39	Sewerage & waste
Construction	F41-43	Construction
Services	G45	Wholesale & retail MV
Services	G46	Wholesale excl MV
Services	G47	Retail excl MV
Services	H49	Land transport, pipelines
Services	H50	Water transport
Services	H51	Air transport
Services	H52	Warehousing
Services	H53	Postal & courier activities
Services	I55-56	Accommodation & food serv
Services	J58	Publishing activities
Services	J59-60	Motion pic, video, television
Services	J61	Telecommunications
Services	J62-63	Computer programming etc.
Services	K64	Financial services
Services	K65	Insurance
Services	K66	Aux to financial services
Services	L681-682	Real estate
Services	L683	Imputed rents
Services	M69-70	Legal, account, consult

Services	M71	Architectural & engineering
Services	M72	R&D
Services	M73	Advertising
Services	M74-75	Other professional
Services	N77	Rental & leasing
Services	N78	Employment activities
Services	N79	Travel agency
Services	N80-82	Security & investigation, etc
Services	O84	Public admin & defence
Services	P85	Education
Services	Q86	Human health activities
Services	Q87-88	Residential care
Services	R90-92	Creative, arts, recreational
Services	R93	Sports activities
Services	S94	Membership orgs
Services	S95	Repair comp. & pers. goods
Services	S96	Other personal serv.
Services	T97	Hholds as employers
Services	T98	Unallocated/Dwellings
Services	U99	Extraterritorial orgs

Table B-2: Country codings and abbreviations

Country code	Country list
AT	Austria
BE	Belgium
BG	Bulgaria
CY	Cyprus
CZ	Czech Republic
DE	Germany
DK	Denmark
EE	Estonia
EL	Greece
ES	Spain
FI	Finland
FR	France
HR	Croatia
HU	Hungary
IE	Ireland
IT	Italy
LT	Lithuania
LU	Luxembourg
LV	Latvia
MT	Malta
NL	Netherlands
PL	Poland
PT	Portugal
RO	Romania
SE	Sweden
SI	Slovenia
SK	Slovakia
UK	United Kingdom
US	United States
JP	Japan

CN	China
RU	Russia
IN	India
KO	Korea
CH	Switzerland
CA	Canada
IO	ITER IO

Annex C: Dataset - specific approach and assumptions

Producing the dataset required bringing together data from various sources and applying a variety of conversion, matching and calculation steps to reach the desired outputs for the econometric analysis. This section briefly explains the key steps that were taken and the assumptions made. The logic and steps taken can also be observed in the dataset.

Data sources

The following datasets were the key sources of contract information:

- F4E payment database;
- F4E – Georeport dataset;
- F4E – GRT and OPE contract dataset;
- F4E – EFDA legacy contract dataset for contracts under articles 5.1 and 7.

There was significant overlap in the first 3 datasets – the team used the F4E payment database as the primary source as this provided actual payments per year, per main contractor, for each contract as also required as input for the econometric analysis. The Georeport dataset was a valuable additional source as this provided for many of the contracts additional information on sub-contractors per contract, and therefore these details were merged into the payment database. The GRT-OPE contract datasets were also checked against the payment database and any contracts not included in the payment database were added to the list.

Inconsistencies were addressed and gaps filled to provide a more complete dataset which could serve as a modelling input for task 2.

Sector matching

Contracts were allocated to NACE codes on the basis of expert judgement, this took into account 3 key matching assessments:

- Matching of contractors to contractor assessments – based on data supplied by F4E a sub-set of contractors have been profiled as specialising in particular technical areas. By allocating a NACE sector to each technical specialisation it was possible to determine a likely NACE sector specialisation for firms on this list;
- Matching by F4E WBS code – based on the code list supplied by F4E it was possible to allocate a primary NACE sector to each 3-digit WBS code. With a 3-digit WBS code available for almost all contracts this provided a minimum basis to allocate a sector to a contract activity;
- Matching to Orbis database of Bureau van Dijk – F4E carried out an extraction of NACE sector profiles for a sub-set of main contractors.

The first two matching approaches were validated by F4E and the independent fusion experts that are part of the project team.

The assessment also took into account the contract description to allocate a NACE sector. All contracts of greater than 500k payment value were manually reviewed. Whilst all below 500k had payments allocated on the basis of their WBS code matching.

Forecasts

The dataset includes an indication of future payments to be made by F4E up to 2034 as part of European contributions to ITER. These forecasts are based on a few key variables and assumptions, including:

- That total EU contributions (and payments) will match the expectations outlined by the European Commission in COM(2017) 319 Final: EU Contribution to a reformed ITER project. Namely that (in current values) total EU ITER spend will be around €18 billion by 2035 (based on table 2 in section III.2);
- With around €2.2 billion paid so far, around €16 billion remains to be spent, of which we estimate around €13.3 billion will be allocated to similar contracts to those included in the current dataset, the remainder being taken up by F4E administration and management;
- Using the Multi-Annual Programme document it is possible to allocate the future spending by the proportions of IUA credits expected in years 2017-2035, this allows payments to be allocated to the WBS 3-digit level across the different actions of the ITER project and also for the total estimated remaining payments to be spread across the years. This approach ensures that the forecasts are not an extrapolation of past spending but are in line with expected EU contributions to specific parts of the ITER programme in the coming years;
- Payments are then allocated to countries using a mixed approach, which allocates:
    - 50% of the expected payments on the basis of the share a particular country had of such payments (per WBS code) in the known payments to mid-2017;
    - 50% of the expected payments on the basis of the share of EU GVA per NACE sector that a country had in the most recent year for which complete data was available (2014). With the WBS code matched to the NACE sector to determine which % to use;
    - On this basis the forecast both includes a portion based on past experience and expectations but also includes a portion allocated on the basis that all member states will be likely to carry out some work for the project, proportional to their economic strengths in the relevant sectors.
- Using the WBS 3-digit level matching to NACE codes it is then possible to allocate the payments to NACE sectors.

This approach is not without limitations and drawbacks, but represents a potential scenario for future spending rooted in the best available current plans and data.

Annex D: Short description of modelling approach and counterfactual scenarios

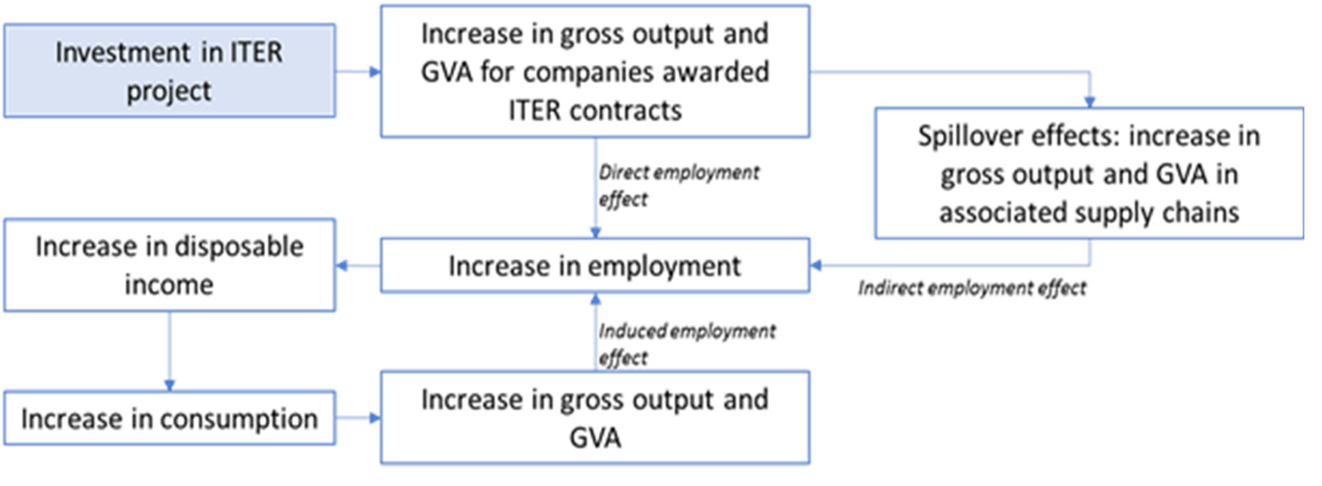
Impact analysis methodology

For the impact analysis the E3ME model was applied to assess the gross value added (GVA) and jobs impacts of the ITER project activities in the EU over the period 2008-2017, for all Member States, disaggregated by all 69 sectors included within the model. As a macro-econometric model, E3ME is already based on an extensive historical database and was thus well placed to carry out this ex-post economic analysis.

The key input to E3ME was the spending on grants or contracts that were awarded to companies based within the EU, for ITER project related activities. This data was collected from F4E within earlier parts of the project and then mapped to the corresponding E3ME sector, allowing for a very detailed analysis of the specific effects of the project.

The input-output structure of E3ME and its detailed representation of industry interdependencies also allowed for the estimation of indirect and spill-over effects of a given investment or grant, through ripple effects in the supply chain. The increase in disposable income and consumption that results from direct and indirect increases in jobs also leads to further job opportunities. This induced impact on jobs was also estimated. The key economic flows reflected in the E3ME model are shown in Figure 0-1 below.

Figure D-1 Key economic flows modelled in E3ME



The key output indicators that we considered for this analysis were direct and indirect GVA impacts (by sector) and direct, indirect and induced jobs impact (by sector). The sectoral results allowed for the assessment of impacts on all 69 E3ME sectors, which we have aggregated to broader industries (e.g. manufacturing, engineering, research, construction, services), for better presentation of the results.

Impact analysis scenario descriptions

Each of the scenarios discussed below were compared to a baseline scenario.

Baseline scenario

For the ex-post analysis the baseline scenario consists of extensive historical data up to 2016. Eurostat data are used wherever possible, supplemented by more specialised sources such as the IEA for energy balances and prices.

Gross impact scenario

The historical data (over 2008-2017) implicitly includes the impact of ITER investments. Therefore, to assess the gross economic contribution of the ITER project we first compared historical out-turn data, which includes ITER investments, to a counterfactual scenario whereby we excluded ITER project investments. This assumes that the investment is not spent elsewhere but is instead saved, and is therefore treated as a leakage from the economy.

Net impact scenario

It was also insightful to assess the net economic impacts of investment in the ITER project to determine what the added benefit was for the EU economy of investing in the ITER programme, compared to spending or investing the equivalent amount elsewhere. For this we developed a scenario where assumptions were made about the specific nature of the alternative investments or spending, and which sectors are the recipients. This scenario also ensured EU revenue neutrality.

It was decided that the most intuitive and unbiased approach was to assume that the total level of investment for each Member State is instead shared across all 69 economic sectors. The share of investment each sector receives is in proportion to that particular sectors' proportion of total output, i.e. if a sector's output contributes 5% of total output, this sector receives 5% of the investment. This approach is more general than comparing the impacts of ITER-related contracts to another specific, 'Big Science' spending programme; however, this sort of comparison was deemed to be too complex for the scope of this study. The more general approach of sharing investment across all sectors, allowed for a wider and more interesting range of results, from which we were able to draw more meaningful analysis.

Cross cutting analysis methodology

The cross cutting analysis of the impacts of ITER project activities included a quantitative assessment of the potential mid-term (until 2030) employment effects using the E3ME model. The econometric specification of E3ME gives the model a strong empirical grounding, basing future trends on what has happened in the past, making it ideal for medium term assessments such as this. This modelling task broadly followed the same methodology as described above for the ex-post analysis. For the cross cutting analysis the inputs to the model were the forecasts of the size and sector distribution of future contracts that were established in earlier tasks of the project. As in the ex-post analysis, these were mapped to the corresponding E3ME sector.

The following paragraphs describe the scenarios that were included in this analysis.

Cross cutting analysis scenario descriptions

Baseline scenario

For the baseline forecast, E3ME was calibrated to match a set of projections that are published by the European Commission and the International Energy Agency. The following gross impact and net impact scenarios represent alternative versions of the future based on a different set of inputs. By comparing the outcomes of these to the baseline, the effects of the change in inputs could be determined.

Gross impact scenario

To assess the future gross employment impacts of ITER project activities up to 2030, we included the projected ITER contracts and grants in the model as purely additional investment compared to the baseline.

Net impact scenario

To determine the net employment impact of future investment in the ITER project we developed an alternative spending scenario to determine the added benefit of investing in the ITER programme, compared to investing the equivalent amount elsewhere. This scenario is based on the same assumptions used for the net impact scenario within the ex-post analysis, i.e. the total level of predicted future ITER investment was instead shared between all 69 economic sectors based on their share of total output.

Impact of spill-overs

To assess the impact of potential spill-overs in each scenario, we start by considering the additional GVA that is generated (or lost) in each case. Based on the 35% of survey respondents who confirmed they had developed new cutting-edge technologies, we assume that 35% of the additional GVA generated by sectors *directly* affected by ITER investment can be attributed to spin offs. We make a further assumption that half of this percentage, i.e. 17.5%, of the additional GVA generated by sectors *indirectly* affected by ITER investment can be attributed to spin offs.

Firms will use part of this increase in GVA to make additional investment. If the scenario leads to a reduction in GVA we assume this is lost GVA that *could have* been used to make further investment. We assume this potential investment may be 50% higher than usual GVA/ investment ratios since investment in new spin-off companies or techniques is likely to be higher than standard investments. The increase/decrease in GVA, plus the likely investments this would have generated is then used as an input to the E3ME model. This allows for an assessment of the impact of spill-overs on jobs and further GVA.

Annex E: E3ME description

Overview

E3ME is a computer-based model of the world's economic and energy systems and the environment. It was originally developed through the European Commission's research framework programmes and is now widely used in Europe and beyond for policy assessment, for forecasting and for research purposes. The global edition is a new version of E3ME which expands the model's geographical coverage from 33 European countries to 59 global regions. It thus incorporates the global capabilities of the previous E3MG model.

Recent applications

Recent applications of E3ME include:

- an ex-post assessment of the socio-economic impact of ESA participation in the ISS programme for the European Space agency;
- an Impact Assessment of the Euratom Loan Facility for DG Ecfin;
- a global assessment of the economic impact of renewables for IRENA;
- contribution to the EU's Impact Assessment of its 2030 climate and energy package;
- an assessment of the potential for green jobs in Europe;
- an economic evaluation for the EU Impact Assessment of the Energy Efficiency Directive.

This model description provides a short summary of the E3ME model. For further details, the reader is referred to the full model manual available online from www.e3me.com.

E3ME's basic structure and data

The structure of E3ME is based on the system of national accounts, with further linkages to energy demand and environmental emissions. The labour market is also covered in detail, including both voluntary and involuntary unemployment. In total there are 33 sets of econometrically estimated equations, also including the components of GDP (consumption, investment, international trade), prices, energy demand and materials demand. Each equation set is disaggregated by country and by sector.

E3ME's historical database covers the period 1970-2014 and the model projects forward annually to 2050. The main data sources for European countries are Eurostat and the IEA, supplemented by the OECD's STAN database and other sources where appropriate. For regions outside Europe, additional sources for data include the UN, OECD, World Bank, IMF, ILO and national statistics. Gaps in the data are estimated using customised software algorithms.

The main dimensions of the model

The main dimensions of E3ME are:

- 59 countries – all major world economies, the EU28 and candidate countries plus other countries' economies grouped;
- 43 or 69 (Europe) industry sectors, based on standard international classifications;
- 28 or 43 (Europe) categories of household expenditure;
- 22 different users of 12 different fuel types;

- 14 types of air-borne emission (where data are available) including the six greenhouse gases monitored under the Kyoto protocol.

The countries and sectors covered by the model are listed at the end of this document.

Standard outputs from the model

As a general model of the economy, based on the full structure of the national accounts, E3ME is capable of producing a broad range of economic indicators. In addition there is range of energy and environment indicators. The following list provides a summary of the most common model outputs:

- GDP and the aggregate components of GDP (household expenditure, investment, government expenditure and international trade);
- sectoral output and GVA, prices, trade and competitiveness effects;
- international trade by sector, origin and destination;
- consumer prices and expenditures;
- sectoral employment, unemployment, sectoral wage rates and labour supply;
- energy demand, by sector and by fuel, energy prices;
- CO_2 emissions by sector and by fuel;
- other air-borne emissions;
- material demands.

This list is by no means exhaustive and the delivered outputs often depend on the requirements of the specific application. In addition to the sectoral dimension mentioned in the list, all indicators are produced at the national and regional level and annually over the period up to 2050.

E3ME as an E3 model

The E3 interactions

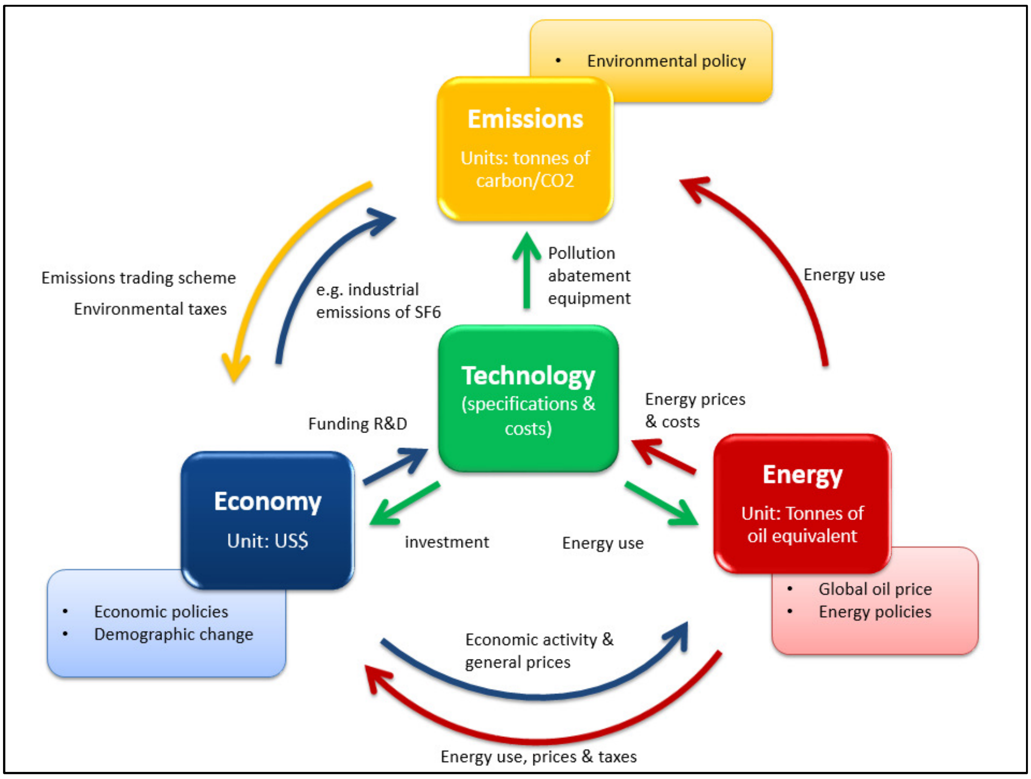
Figure A-1 shows how the three components (modules) of the model - energy, environment and economy - fit together. Each component is shown in its own box. Each data set has been constructed by statistical offices to conform with accounting conventions. Exogenous factors coming from outside the modelling framework are shown on the outside edge of the chart as inputs into each component. For each region's economy the exogenous factors are economic policies (including tax rates, growth in government expenditures, interest rates and exchange rates). For the energy system, the outside factors are the world oil prices and energy policy (including regulation of the energy industries). For the environment component, exogenous factors include policies such as reduction in SO_2 emissions by means of end-of-pipe filters from large combustion plants. The linkages between the components of the model are shown explicitly by the arrows that indicate which values are transmitted between components.

The economy module provides measures of economic activity and general price levels to the energy module; the energy module provides measures of emissions of the main air pollutants to the environment module, which in turn can give measures of damage to health and buildings. The energy module provides detailed price levels for energy carriers distinguished in the economy module and the overall price of energy as well as energy use in the economy.

The role of technology

Technological progress plays an important role in the E3ME model, affecting all three Es: economy, energy and environment. The model's endogenous technical progress indicators (TPIs), a function of R&D and gross investment, appear in nine of E3ME's econometric equation sets including trade, the labour market and prices. Investment and R&D in new technologies also appears in the E3ME's energy and material demand equations to capture energy/resource savings technologies as well as pollution abatement equipment. In addition, E3ME also captures low carbon technologies in the power sector through the FTT power sector model[97].

Figure E-1 E3 linkages in the E3ME model



Treatment of international trade

An important part of the modelling concerns international trade. E3ME solves for detailed bilateral trade between regions (similar to a two-tier Armington model). Trade is modelled in three stages:

- econometric estimation of regions' sectoral import demand;
- econometric estimation of regions' bilateral imports from each partner;
- forming exports from other regions' import demands.

Trade volumes are determined by a combination of economic activity indicators, relative prices and technology.

The labour market

Treatment of the labour market is an area that distinguishes E3ME from other macroeconomic models. E3ME includes econometric equation sets for employment, average working hours, wage rates and

[97] See Mercure (2012).

participation rates. The first three of these are disaggregated by economic sector while participation rates are disaggregated by gender and five-year age band.

The labour force is determined by multiplying labour market participation rates by population. Unemployment (including both voluntary and involuntary unemployment) is determined by taking the difference between the labour force and employment. This is typically a key variable of interest for policy makers.

Comparison with CGE models and econometric specification

E3ME is often compared to Computable General Equilibrium (CGE) models. In many ways, the modelling approaches are similar; they are used to answer similar questions and use similar inputs and outputs. However, underlying this there are important theoretical differences between the modelling approaches.

In a typical CGE framework, optimal behaviour is assumed, output is determined by supply-side constraints and prices adjust fully so that all the available capacity is used. In E3ME the determination of output comes from a post-Keynesian framework and it is possible to have spare capacity. The model is more demand-driven and it is not assumed that prices always adjust to market clearing levels. The differences have important practical implications, as they mean that in E3ME regulation and other policy may lead to increases in output if they are able to draw upon spare economic capacity. This is described in more detail in the model manual.

The econometric specification of E3ME gives the model a strong empirical grounding. E3ME uses a system of error correction, allowing short-term dynamic (or transition) outcomes, moving towards a long-term trend. The dynamic specification is important when considering short and medium-term analysis (e.g. up to 2020) and rebound effects[98], which are included as standard in the model's results.

Key strengths of E3ME

In summary the key strengths of E3ME are:

- the close integration of the economy, energy systems and the environment, with two-way linkages between each component;
- the detailed sectoral disaggregation in the model's classifications, allowing for the analysis of similarly detailed scenarios;
- its global coverage, while still allowing for analysis at the national level for large economies;
- the econometric approach, which provides a strong empirical basis for the model and means it is not reliant on some of the restrictive assumptions common to CGE models;
- the econometric specification of the model, making it suitable for short and medium-term assessment, as well as longer-term trends.

Applications of E3ME

Scenario-based analysis

Although E3ME can be used for forecasting, the model is more commonly used for evaluating the impacts of an input shock through a scenario-based analysis. The shock may be either a change in

[98] Where an initial increase in efficiency reduces demand, but this is negated in the long run as greater efficiency lowers the relative cost and increases consumption. See Barker et al (2009).

policy, a change in economic assumptions or another change to a model variable. The analysis can be either forward looking (ex-ante) or evaluating previous developments in an ex-post manner. Scenarios may be used either to assess policy, or to assess sensitivities to key inputs (e.g. international energy prices).

For ex-ante analysis a baseline forecast up to 2050 is required; E3ME is usually calibrated to match a set of projections that are published by the European Commission and the IEA but alternative projections may be used. The scenarios represent alternative versions of the future based on a different set of inputs. By comparing the outcomes to the baseline (usually in percentage terms), the effects of the change in inputs can be determined.

It is possible to set up a scenario in which any of the model's inputs or variables are changed. In the case of exogenous inputs, such as population or energy prices, this is straight forward. However, it is also possible to add shocks to other model variables. For example, investment is endogenously determined by E3ME, but additional exogenous investment (e.g. through an increase in public investment expenditure) can also be modelled as part of a scenario input.

Table E-1: Main dimensions of the E3ME model. Source(s): Cambridge Econometrics.

	Regions	Industries (Europe)	Industries (non-Europe)
1	Belgium	Crops, animals, etc	Agriculture etc
2	Denmark	Forestry & logging	Coal
3	Germany	Fishing	Oil & Gas etc
4	Greece	Coal	Other Mining
5	Spain	Oil and Gas	Food, Drink & Tobacco
6	France	Other mining	Textiles, Clothing & Leather
7	Ireland	Food, drink & tobacco	Wood & Paper
8	Italy	Textiles & leather	Printing & Publishing
9	Luxembourg	Wood & wood prods	Manufactured Fuels
10	Netherlands	Paper & paper prods	Pharmaceuticals
11	Austria	Printing & reproduction	Other chemicals
12	Portugal	Coke & ref petroleum	Rubber & Plastics
13	Finland	Other chemicals	Non-Metallic Minerals
14	Sweden	Pharmaceuticals	Basic Metals
15	UK	Rubber & plastic products	Metal Goods
16	Czech Rep.	Non-metallic mineral prods	Mechanical Engineering
17	Estonia	Basic metals	Electronics
18	Cyprus	Fabricated metal prods	Electrical Engineering
19	Latvia	Computers etc	Motor Vehicles
20	Lithuania	Electrical equipment	Other Transport Equipment
21	Hungary	Other machinery/equipment	Other Manufacturing
22	Malta	Motor vehicles	Electricity
23	Poland	Other transport equip	Gas Supply
24	Slovenia	Furniture; other manufacture	Water Supply
25	Slovakia	Machinery repair/installation	Construction
26	Bulgaria	Electricity	Distribution
27	Romania	Gas, steam & air cond.	Retailing
28	Norway	Water, treatment & supply	Hotels & Catering

	Regions	Industries (Europe)	Industries (non-Europe)
29	Switzerland	Sewerage & waste	Land Transport etc
30	Iceland	Construction	Water Transport
31	Croatia	Wholesale & retail MV	Air Transport
32	Turkey	Wholesale excl MV	Communications
33	Macedonia	Retail excl MV	Banking & Finance
34	USA	Land transport, pipelines	Insurance
35	Japan	Water transport	Computing Services
36	Canada	Air transport	Professional Services
37	Australia	Warehousing	Other Business Services
38	New Zealand	Postal & courier activities	Public Administration
39	Russian Fed.	Accommodation & food serv	Education
40	Rest of Annex I	Publishing activities	Health & Social Work
41	China	Motion pic, video, television	Miscellaneous Services
42	India	Telecommunications	Unallocated
43	Mexico	Computer programming etc.	
44	Brazil	Financial services	
45	Argentina	Insurance	
46	Colombia	Aux to financial services	
47	Rest Latin Am.	Real estate	
48	Korea	Imputed rents	
49	Taiwan	Legal, account, consult	
50	Indonesia	Architectural & engineering	
51	Rest of ASEAN	R&D	
52	Rest of OPEC	Advertising	
53	Rest of world	Other professional	
54	Ukraine	Rental & leasing	
55	Saudi Arabia	Employment activities	
56	Nigeria	Travel agency	
57	South Africa	Security & investigation, etc	
58	Rest of Africa	Public admin & defence	
59	Africa OPEC	Education	
60		Human health activities	
61		Residential care	
62		Creative, arts, recreational	
63		Sports activities	
64		Membership orgs	
65		Repair comp. & pers. goods	
66		Other personal serv.	
67		Hholds as employers	
68		Extraterritorial orgs	
69		Unallocated/Dwellings	

Annex F: Detailed modelling results data

Chapter 3 - ex-post analysis detailed results

Gross results

Table F-1: Impact on employment of the ITER programme by Member State, 000's difference from baseline

Country	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	Total job years
BE	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.2	1.3
DK	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1
DE	0.0	0.3	-0.2	0.2	0.2	0.1	0.2	0.1	0.4	0.9	2.2
EL	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1
ES	0.3	0.5	0.7	1.0	1.1	1.5	1.8	2.0	2.2	2.4	13.4
FR	0.3	0.2	0.5	0.9	0.8	1.0	1.1	1.5	2.1	2.4	10.7
IE	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2
IT	0.1	0.0	0.1	0.1	0.2	0.2	0.2	0.2	0.3	0.5	1.9
LX	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
NL	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
AT	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1
PT	0.0	0.0	0.0	0.0	0.1	0.0	0.1	0.2	0.3	0.3	1.0
FI	0.1	0.0	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.2	1.1
SW	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
UK	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1
CZ	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.1	0.3
EN	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
CY	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
LV	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
LT	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1
HU	-0.1	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.1	0.2
MT	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
PL	-0.1	0.0	0.0	0.0	0.1	0.1	0.1	-0.1	-0.3	-0.2	-0.3
SI	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
SK	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1
BG	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
RO	0.0	0.0	0.0	0.1	0.1	0.1	0.2	0.2	0.2	0.2	1.0
HR	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Sources: E3ME, Cambridge Econometrics.

Note: Not all totals may sum due to rounding

Table F-2: Impact of the ITER programme on GVA by Member State, absolute difference from baseline (m 2015 €)

Country	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	Total cumulated
BE	5.9	8.5	9.4	11.3	11.5	12.5	15.1	14.6	17.2	25.8	131.9
DK	-0.5	0.1	0.4	0.7	1.3	1.7	2.2	3.6	5.0	8.8	23.5
DE	2.5	17.6	8.9	15.9	41.3	34.1	39.6	35.9	49.8	112.2	357.8
EL	-0.1	0.2	0.3	0.5	0.7	1.0	1.8	2.0	2.1	3.5	12.1
ES	16.2	26.8	47.9	61.9	71.9	94.9	133.7	143.3	154.2	200.3	951.1
FR	103.4	49.6	108.9	167.8	166.4	242.0	309.0	363.7	459.2	532.1	2502.2
IE	-0.1	0.0	0.8	1.6	7.8	2.5	0.8	1.5	2.0	6.6	23.5
IT	9.2	3.4	31.3	31.5	66.3	46.4	92.1	87.8	100.0	130.0	598.0
LX	0.0	0.0	0.0	0.0	0.1	0.1	0.1	0.1	0.1	0.5	1.1
NL	0.0	0.0	0.0	0.0	0.1	0.1	0.1	0.2	0.2	2.8	3.5
AT	-0.2	0.5	0.8	2.2	3.9	4.8	5.9	6.9	5.3	18.0	48.1
PT	-1.0	0.4	0.6	1.1	3.4	2.9	5.3	11.8	13.3	18.3	56.1
FI	10.2	2.5	12.5	5.7	11.3	5.5	5.9	16.4	21.6	30.1	121.7
SW	0.7	0.8	0.8	1.4	1.7	1.6	2.2	-3.5	-10.6	-4.4	-9.3
UK	0.0	0.0	1.7	3.8	2.8	3.5	4.0	4.3	4.4	18.5	43.0
CZ	2.0	0.5	1.5	2.0	2.9	3.5	5.5	-6.9	-7.7	-0.4	2.8
EN	-0.2	0.1	0.0	0.1	0.1	0.2	0.2	0.3	0.3	0.6	1.7
CY	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.1	0.1	0.1	0.5
LV	0.0	0.0	0.0	0.1	0.1	0.2	0.3	-0.1	-0.2	-0.4	-0.1
LT	0.0	0.0	0.1	0.1	0.2	0.3	0.4	0.7	0.9	1.4	3.9
HU	-3.7	0.9	-0.1	0.6	1.1	1.9	3.2	0.4	1.8	5.4	11.7
MT	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.2	0.4
PL	-2.2	0.8	0.6	1.8	2.9	3.5	5.2	-18.3	-36.4	-36.7	-78.6
SI	-0.2	0.2	0.3	0.4	0.6	0.7	1.2	-1.2	-1.7	-1.2	-0.8
SK	-0.4	0.1	0.5	0.4	0.7	0.5	0.8	2.4	-1.4	10.9	14.4
BG	0.0	0.0	0.1	0.1	0.1	0.1	0.2	0.3	0.6	0.8	2.4
RO	-0.1	0.6	1.1	1.2	2.3	3.1	4.3	5.0	6.1	10.2	33.8
HR	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Sources: E3ME, Cambridge Econometrics.

Notes: The sum of changes is in real terms but not otherwise discounted.

Net results

Table F-3: Impact of the ITER programme (rather than alternative investment) on employment by Member State, 000's difference from baseline

Country	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	Total job years
BE	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	1.0
DK	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
DE	-0.1	0.1	-0.3	0.1	0.0	0.0	0.0	-0.1	0.0	0.0	-0.1
EL	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
ES	0.2	0.3	0.4	0.5	0.5	0.6	0.7	0.7	0.6	0.5	4.9
FR	0.0	-0.1	0.1	0.3	0.2	0.2	0.1	0.1	0.2	0.2	1.2
IE	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
IT	0.0	0.0	-0.1	-0.1	-0.2	-0.2	-0.4	-0.4	-0.4	-0.4	-2.2
LX	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
NL	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
AT	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
PT	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.1	0.1	0.1	0.3
FI	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
SW	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
UK	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
CZ	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-0.1	-0.1	-0.2
EN	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
CY	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
LV	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
LT	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
HU	-0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-0.1	-0.1	-0.1
MT	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
PL	-0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.2	0.3	0.8
SI	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
SK	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.0	0.3
BG	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
RO	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-0.2
HR	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Sources: E3ME, Cambridge Econometrics.

Table F-4: Impact of ITER (rather than alternative investment) on GVA by Member State, absolute difference from baseline (m 2015 €)

Country	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	Total cumulated
BE	0.5	2.1	2.1	2.8	2.7	2.8	3.2	1.9	1.8	3.4	23.2
DK	-0.4	0.0	0.0	0.2	0.4	0.5	0.6	0.6	-0.1	-0.9	0.9
DE	-5.6	2.7	-5.4	0.8	3.0	1.3	-0.3	-2.4	-4.7	-16.5	-27.2
EL	0.0	0.1	0.2	0.1	0.2	0.1	0.5	0.6	0.2	0.0	2.1
ES	1.9	6.9	10.1	13.1	13.3	13.7	17.5	19.1	18.4	16.2	130.3
FR	-6.9	-10.0	-7.5	1.7	13.8	12.3	13.7	-2.7	-7.8	-36.0	-29.4
IE	-0.1	-0.1	0.1	0.2	1.6	-0.2	-0.2	0.0	0.1	0.4	1.8
IT	-1.5	-5.6	-0.4	-1.3	3.0	0.4	1.6	-1.2	-5.6	-13.9	-24.4
LX	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.0	0.2	0.6
NL	-0.3	0.0	0.0	0.0	-0.1	0.0	-0.1	-0.2	-0.1	1.0	0.2
AT	-0.6	0.4	0.4	0.9	1.5	1.7	2.3	1.6	1.5	-1.7	7.9
PT	-0.8	0.1	0.3	0.5	0.6	0.6	1.1	0.1	1.7	0.0	4.3
FI	1.7	-0.1	-0.6	-0.1	-0.7	-1.3	-2.0	-2.4	2.4	2.7	-0.5
SW	-1.1	0.4	0.4	0.8	1.1	1.4	2.1	-0.9	-4.0	-9.2	-9.0
UK	-0.7	-0.5	0.7	1.7	0.9	1.1	1.1	1.2	0.6	7.7	13.8
CZ	0.0	0.0	0.5	0.5	1.1	1.2	2.0	-7.1	-8.7	-5.4	-16.0
EN	-0.2	0.1	0.0	0.1	0.0	0.0	0.0	0.1	0.0	-0.1	0.1
CY	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1
LV	0.0	0.0	0.0	0.0	0.0	0.0	0.1	-0.3	-0.4	0.2	-0.4
LT	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.3	0.3	0.2	0.9
HU	-2.8	0.9	0.4	0.9	0.5	0.7	1.1	-5.1	-7.8	4.7	-6.6
MT	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1
PL	-1.6	0.5	0.2	1.0	1.0	1.4	1.7	4.2	15.7	28.3	52.4
SI	-0.2	0.1	0.2	0.1	0.1	0.1	0.2	-0.9	-1.6	-1.6	-3.5
SK	-0.4	0.2	0.7	1.4	2.0	2.4	3.7	4.5	8.1	-4.2	18.4
BG	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.4	0.4	1.0
RO	-1.1	-0.1	-0.2	-0.6	-0.3	-0.7	-0.6	-0.2	-0.1	0.1	-3.9
HR	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Sources: E3ME, Cambridge Econometrics.

Notes: The sum of changes is in real terms but not otherwise discounted.

Chapter 4 - forecast analysis 2018-2030

Gross results

Table F-5: Total EU28 impact on employment of the ITER programme, 000's difference from baseline

Country	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	Total job years
BE	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.1	0.1	0.1	0.1	0.1	2.1
DK	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3
DE	1.4	1.2	1.2	1.1	1.0	1.0	1.0	0.8	0.6	0.7	0.6	0.5	0.6	11.7
EL	0.0	0.0	0.1	0.1	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4
ES	2.0	1.9	1.9	1.9	1.8	1.8	1.7	1.6	1.3	1.2	1.1	1.0	1.1	20.3
FR	0.7	0.8	1.1	1.2	1.5	1.5	1.4	1.2	1.0	0.8	0.6	0.5	0.5	13.0
IE	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4
IT	0.9	0.8	0.8	0.9	0.7	0.6	0.5	0.3	0.2	0.3	0.2	0.2	0.2	6.5
LX	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
NL	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.2	0.2	0.2	0.2	1.8
AT	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.7
PT	0.1	0.1	0.2	0.1	0.2	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.0	1.5
FI	0.2	0.2	0.2	0.1	0.1	0.1	0.1	0.1	0.1	0.0	0.0	0.0	0.0	1.2
SW	0.1	0.1	0.1	0.1	0.0	0.0	0.1	0.1	0.1	0.1	0.1	0.1	0.0	0.8
UK	0.4	0.3	0.3	0.3	0.4	0.4	0.4	0.4	0.3	0.3	0.3	0.3	0.2	4.4
CZ	0.1	0.1	0.2	0.2	0.2	0.2	0.2	0.2	0.1	0.1	0.0	0.0	0.0	1.6
EN	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
CY	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1
LV	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2
LT	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2
HU	0.0	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.0	0.0	1.0
MT	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
PL	0.4	0.2	0.3	0.2	0.1	0.1	0.2	0.2	0.0	0.0	-0.1	0.0	-0.1	1.6
SI	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2
SK	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.6
BG	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-0.1
RO	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.1	0.1	0.0	0.0	0.0	1.9
HR	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3

Sources: E3ME, Cambridge Econometrics.

Table F-6: Impact of the ITER programme on GVA by Member State, absolute difference from baseline (m 2015 €)

Country	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	Total cumulative
BE	30.0	27.7	32.4	33.4	33.9	38.6	39.8	39.3	37.0	40.8	35.7	36.7	31.5	457.0
DK	7.5	5.7	7.6	7.9	8.0	8.9	10.3	11.7	10.6	13.1	10.4	9.4	9.2	120.3
DE	226.1	169.7	195.3	226.3	179.8	213.5	198.0	144.5	98.6	151.6	80.1	85.8	83.5	2052.7
EL	4.5	4.1	4.7	4.9	4.7	5.2	5.1	4.0	3.2	3.3	3.3	0.7	1.1	48.8
ES	174.8	146.0	169.3	171.6	168.7	177.6	182.3	176.6	157.6	170.2	140.7	130.2	157.3	2123.0
FR	394.8	335.4	428.1	480.5	502.5	523.0	539.3	494.6	544.4	562.6	473.4	330.7	308.1	5917.5
IE	10.1	6.9	10.1	7.8	5.5	7.1	7.2	7.8	6.0	10.4	6.1	4.1	3.8	92.8
IT	208.8	162.3	165.3	186.0	128.3	137.8	128.9	105.6	88.4	102.6	77.3	59.3	50.7	1601.4
LX	0.3	0.1	0.5	0.1	0.1	-0.2	-0.4	-0.4	-0.6	-0.7	-0.7	-0.6	-0.4	-2.9
NL	31.6	25.9	29.9	30.6	27.6	31.5	31.8	28.7	23.7	29.3	21.5	18.9	18.9	349.8
AT	20.1	15.4	17.2	17.8	14.9	21.9	22.1	19.2	14.2	22.4	10.2	9.9	4.7	210.0
PT	12.0	8.7	13.6	11.8	12.5	12.5	12.7	12.4	10.4	12.7	8.7	5.7	4.8	138.4
FI	32.0	21.4	24.0	19.4	16.1	19.6	18.6	16.9	11.5	14.0	6.2	4.0	2.8	206.6
SW	18.2	14.6	18.6	18.6	17.5	18.2	17.6	15.5	12.0	15.2	8.9	6.8	5.6	187.4
UK	72.1	49.8	75.2	62.4	109.9	99.6	99.7	80.0	61.8	72.1	49.2	48.4	6.0	886.2
CZ	13.4	11.8	12.6	13.9	12.6	14.9	15.6	13.1	8.2	8.7	5.0	4.3	5.9	140.1
EN	0.9	0.8	1.1	0.9	0.9	0.8	1.9	0.8	-0.8	2.2	1.3	1.1	0.2	11.9
CY	0.5	0.4	0.5	0.5	0.6	0.6	0.7	0.6	0.5	0.5	0.4	0.3	0.2	6.2
LV	1.0	0.8	1.3	1.2	1.2	1.0	2.0	1.0	-0.8	1.0	-0.2	0.3	0.0	9.8
LT	1.4	0.9	1.3	1.2	1.3	1.4	1.5	1.4	1.0	1.3	0.9	0.7	0.6	15.0
HU	5.4	5.0	5.3	6.4	10.1	13.2	13.5	11.8	5.7	7.1	4.5	2.7	5.5	96.2
MT	0.2	0.1	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.1	2.5
PL	25.4	19.7	22.7	21.8	19.6	22.1	25.1	22.1	16.0	22.3	13.4	12.0	9.8	252.0
SI	3.7	3.1	3.5	4.1	3.3	4.5	4.5	3.1	1.9	3.2	1.6	1.9	1.5	39.9
SK	7.8	5.8	6.7	6.6	6.1	7.1	7.5	5.9	4.5	6.9	4.1	4.1	3.8	76.9
BG	0.3	0.3	0.2	0.2	0.2	0.3	0.4	0.5	0.5	0.7	0.7	0.8	0.6	5.6
RO	11.4	9.8	10.7	10.6	9.5	12.1	14.3	12.3	8.0	9.0	9.3	9.3	11.5	137.9
HR	1.0	0.9	1.0	1.0	0.8	1.1	0.9	0.9	0.8	1.0	0.6	0.6	0.7	11.4

Sources: E3ME, Cambridge Econometrics.

Notes: The cumulated figures are in real terms but not further discounted.

Net results

Table F-7: Impact of the ITER programme (rather than alternative investment) on employment by Member State, 000's difference from baseline

Country	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	Total job years
BE	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	1.2
DK	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1
DE	-0.1	-0.1	0.0	-0.2	-0.2	-0.3	-0.3	-0.2	-0.1	-0.1	0.0	0.0	0.0	-1.6
EL	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
ES	0.4	0.4	0.3	0.5	0.5	0.6	0.6	0.6	0.6	0.5	0.5	0.5	0.6	6.5
FR	-0.4	-0.3	-0.3	-0.4	-0.3	-0.3	-0.5	-0.6	-0.8	-0.9	-0.9	-0.7	-0.4	-7.0
IE	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
IT	0.0	0.1	0.1	0.1	0.1	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.5
LX	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
NL	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.1	0.1	0.5
AT	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-0.2
PT	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-0.1
FI	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2
SW	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-0.1
UK	0.0	0.0	0.0	0.0	-0.1	-0.1	0.0	0.0	0.0	0.1	0.1	0.1	0.0	0.0
CZ	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
EN	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
CY	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
LV	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
LT	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
HU	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-0.2
MT	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
PL	0.0	0.0	-0.1	0.0	-0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-0.4
SI	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
SK	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
BG	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
RO	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-0.1	-0.1	-0.1	-0.1	0.0	0.0	-0.5
HR	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1

Sources: E3ME, Cambridge Econometrics.

Table F-8: Impact of ITER (rather than alternative investment) on GVA by Member State, absolute difference from baseline (m 2015 €)

Country	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	Total cumulated
BE	4.6	4.8	5.0	6.1	6.6	7.9	8.3	8.5	8.4	8.6	8.4	8.2	8.3	93.8
DK	-0.2	-0.5	-0.4	-0.7	0.0	0.1	0.7	1.1	1.1	1.6	1.3	1.8	3.0	8.9
DE	0.2	1.5	6.9	2.1	-10.9	-11.0	-17.0	-5.6	-2.8	-1.6	-3.0	-2.6	1.1	-42.7
EL	0.7	0.7	0.6	0.5	0.1	0.3	0.1	0.4	0.2	0.0	-0.3	-0.5	-0.1	2.8
ES	17.7	20.2	21.3	27.0	35.0	36.4	38.8	37.1	34.0	32.6	33.4	35.5	39.9	408.9
FR	-22.9	-23.0	-26.9	-26.8	-18.8	-14.0	-16.8	-20.6	-16.6	-15.3	-26.0	-16.3	2.1	-242.0
IE	0.6	-0.2	0.1	-0.7	-2.0	-0.7	-0.6	0.0	0.5	0.7	0.6	1.7	0.4	0.4
IT	1.5	5.7	2.3	-2.3	8.1	8.0	12.5	12.7	11.5	9.9	8.4	2.8	5.3	86.4
LX	0.2	0.1	0.3	0.2	0.2	0.1	0.1	-0.1	-0.2	-0.3	-0.2	-0.3	-0.4	-0.3
NL	0.4	2.0	0.6	2.2	1.5	2.0	2.9	2.3	2.8	4.7	4.9	6.5	7.6	40.4
AT	-0.1	-1.0	-0.6	-0.7	-0.1	-1.9	-0.7	-1.5	0.8	0.8	3.1	3.2	2.9	4.3
PT	0.5	0.2	0.9	0.6	0.9	0.7	0.8	0.8	0.7	0.9	0.5	0.4	0.5	8.5
FI	-1.3	0.6	0.3	1.7	2.0	2.2	1.4	1.0	0.3	-0.3	0.0	2.0	1.8	11.9
SW	-0.6	-0.6	-0.4	-1.4	-1.8	-2.7	-3.0	-2.4	-2.3	-1.9	-1.4	-0.8	-0.1	-19.2
UK	8.1	4.7	7.6	4.2	13.6	8.0	8.0	5.7	4.4	5.9	4.7	3.7	-0.9	77.8
CZ	0.6	0.6	0.1	-0.8	0.0	1.3	2.1	1.4	-0.5	-1.7	-2.0	-1.2	1.8	1.7
EN	0.0	0.1	0.1	0.1	0.2	0.2	0.2	0.3	0.3	0.4	0.0	-0.4	0.1	1.5
CY	0.1	0.0	0.0	0.0	0.0	0.1	0.1	0.1	0.1	0.1	0.0	0.0	-0.1	0.6
LV	0.2	0.2	0.3	0.2	0.2	0.3	0.2	0.1	0.0	0.2	-0.1	-0.3	0.1	1.5
LT	0.0	0.1	0.1	0.2	0.3	0.4	0.4	0.4	0.3	0.4	0.3	-0.1	0.0	2.8
HU	-0.9	-1.0	-1.2	-0.8	-0.5	1.9	1.9	-0.3	-2.4	-3.4	-3.2	-3.3	-1.0	-14.0
MT	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4
PL	0.7	0.2	-0.9	-0.9	-0.6	1.2	2.8	3.1	2.9	3.7	3.2	3.1	4.1	22.7
SI	0.2	0.3	0.1	0.3	0.3	0.6	0.6	-0.1	-0.5	-0.3	-0.4	-0.1	0.3	1.3
SK	0.0	-0.3	-0.7	-0.2	0.3	0.6	0.5	-0.3	-0.3	0.4	0.0	0.1	0.6	0.6
BG	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.2	0.2	0.1	0.0	-0.2	0.4
RO	-1.0	0.1	-0.4	-2.0	-0.7	-1.0	-1.7	-1.5	-3.3	-4.1	-3.3	-3.3	0.4	-21.8
HR	0.1	0.1	0.1	0.1	0.0	0.2	0.1	0.1	0.2	0.3	0.1	0.3	0.4	2.2

Sources: E3ME, Cambridge Econometrics.

Notes: The cumulated figures are in real terms but not further discounted.

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